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Use of vegetation maps to infer on the ecological suitability of species using central and western Kenya as an example

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Kindt, Roeland; van Breugel, Paolo; Lillesø, Jens-Peter Barnekow

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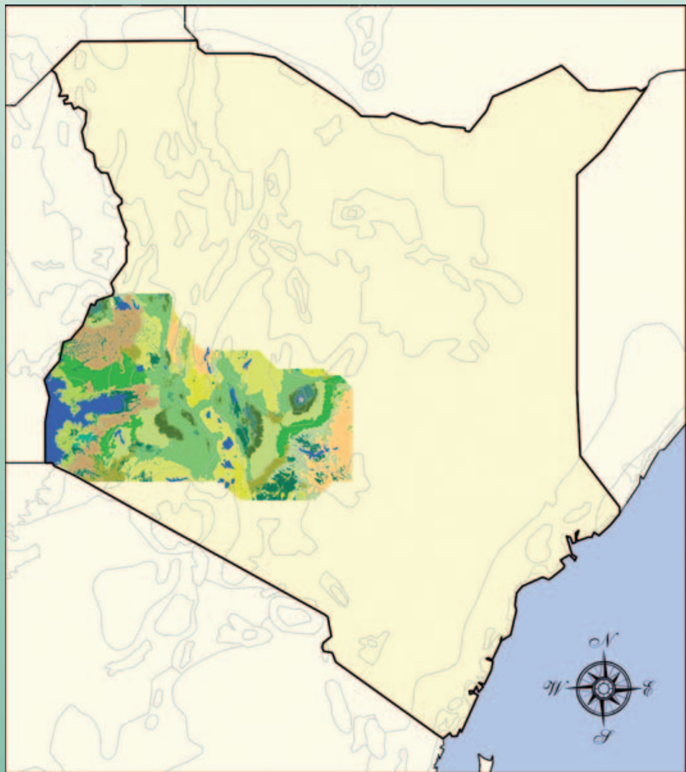

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Titel

Use of vegetation maps to infer on the ecological suitability of species using central and western Kenya as an example
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Authors

Roeland Kindt[1], Paulo van Breugel[1] and Jens-Peter Barnekow Lillesø[2]

Collaborating Partners

World Agroforestry Center[1], Nairobi, Kenya

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Front page image

The digitized vegetation map of Southwest Kenya superimposed on the Kenya map (thick lines). The vague lines show the outlines of the vegetation types of White's (1983) vegetation map of Africa.

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Acronyms

ALP	Alpine
BAM	Bamboo woodland and thicket
CEC	Cation Exchange Capacity
DCO	Dry *Combretum* savanna
DEM	Digital Elevation Model
DIF	Dry Intermediate forest
DM	Number of Dry Months
DMF	Dry Montane forest
EB	Evergreen and semi-evergreen bushland
IAC	*Acacia* and allied vegetation on soils with impeded drainage
LAC	Lowland *Acacia-Commiphora* woodland, bushland and thicket
MCO	Moist *Combretum-Terminalia* savanna
MIF	Moist Intermediate forest
MIX	Broad-leaved savanna-evergreen bushland mixtures
MMF	Moist Montane forest
MSM	Mountain scrubland and moorland
OGR	Open grassland areas on clay plains
P	Annual Precipitation
PET	Annual Potential Evapotranspiration
PNV	Potential Natural Vegetation
RD	Rootable depth
SET	Semi-evergreen thicket
SWA	*Papyrus* and swamp
T_{min}	Mean minimum Temperature of the coldest month
TWI	Topographic Wetness Index
UAC	Upland *Acacia* woodland, savanna and bushland

Contents

1. Introduction

Vegetation maps show classifications of plant communities based on differences in floristics (composition and relative abundances of species), physiognomic structure (such as growth form, height, ground cover, type of leaves) and seasonal activity patterns (van der Maarel 2005, Box and Fujiwara 2005). Potential natural vegetation (PNV) has been defined as the vegetation structure that would become established if all successional sequences were completed without interference by man under the present climatic and edaphic (soil) conditions, including those created by man (Tüxen 1956, Mueller-Dombois and Ellenberg 1974, Box and Fujiwara 2005). This definition makes it clear that PNV is not necessarily the original vegetation as the site conditions may have changed after the original vegetation was removed.

Maps of the PNV of large regions have been produced, including global maps and maps for Africa, tropical Asia, South America and the mainland USA (Box and Fujiwara 2005). These maps have been used in land use planning (e.g., Froude 1999, Wells *et al.* 2004, Global Forest Watch 2006), for the design of conservation strategies (e.g., Olson *et al.* 2001), for studies of species distribution (e.g. Pearce *et al.* 2001, Pearce and Ferrier 2001, Peterson *et al.* 2001, Franklin 2002, Kindt *et al.* 2007) and for the determination of seed, provenance, tree planting, or genecological zones (Graudal *et al.*, 1997; Lillesø et al, 2001). PNV maps are a promising tool for bringing indigenous tree species into use within anthropogenic landscapes, but such maps have unfortunately been ignored largely by the agroforestry world. The purpose of our studies of PNV of eastern Africa is therefore to document how the utility of PNV maps can be increased. As a documentation of the approach, we used a detailed PNV map that was developed for the highlands of Kenya and the adjacent areas.

Trapnell and his co-workers (Trapnell *et al.* 1966, 1969, 1976, 1986; Trapnell and Brunt 1987) produced four sheets of a vegetation map for south-western Kenya on a scale of 1:250 000 that mapped vegetation as it was in 1960 (hereafter called the 'original map'). We believe that the original map is still useful today as, despite the fact that the main aerial and field surveys were completed in the early 1960s, the map allowed to determine the PNV of the mapped area. Given that the distribution of species can be linked with the distribution of PNV, the new PNV map that we developed can assist in selecting species for particular locations within the map. Such selections can be linked conceptually to the ecological definition of agroforestry in 'mimicking natural ecosystems', which we interpret here to the detail of establishing similar tree species assemblages as those that were occurring under natural conditions.

Although Trapnell and his co-authors were aware of possible limitations of their approach as they acknowledged that vegetation is changing, they did see the purpose of their maps as a tool for landuse planning:

»The use of ecological zones for agricultural development planning rested on the concept that climax vegetation communities develop in response to local limitations of climate and soil. In the absence of detailed soil survey and a complete network of climatic stations, mapping climax vegetation is therefore an indirect means of establishing the limits of different eco-climatic zones, each suitable for a specific range of crops« (Trapnell and Brunt 1987, p. 1).

»Vegetation (…) is constantly changing under the several influences of fire, grazing, cultivation and timber extraction. This applies particularly to the climax forest areas (…). This fact, however, in no way invalidates the concept of using vegetation as an index of land potential« (Trapnell and Brunt 1987, p. 4).

Although Trapnell and his co-workers produced a detailed map, the documentation of the used methodology (i.e., Trapnell and Brunt 1987) in differentiating between different vegetation types lacks detail, especially since they did not provide the exact criteria that were used to differentiate between the various types. As we are convinced that the detail of the original vegetation maps was justified given the amount of survey work and the information provided within the limited documentation, the main attempt of this document is to provide a more comprehensive description of the PNV types for which the maps show detailed patterns of distribution. We used two main sources for these additional descriptions for PNV types:

(i) information available from literature on vegetation types that cover the area of the original map; and
(ii) information available from spatial datasets that cover the area of the original map.

The correspondence between PNV types provided in the new map and those described in other literature sources also enabled us to expand vegetation-specific species lists (Kindt *et al.* 2007). Even if information from spatial datasets do not provide clear thresholds between different PNV types, the map could simply be used as a summary of the main climatic and soil conditions within the mapped boundaries given the objectives of maps to provide abstractions of spatial patterns.

2. Methods

2.1 Determination of potential natural vegetation types

It is unfortunate that the original vegetation maps and their documentation provide little information on the criteria that were used to distinguish between the different vegetation types. Although the boundaries between the vegetation types are provided on the map on a scale of 1:250 000, no information was provided on the actual criteria that were used to distinguish between the types on aerial photographs and during fieldwork.

Vegetation boundaries of the original maps were determined by aerial photographs (1:30 000 photographs for 1945 – 1950; 1:50 000 photographs for 1957 – 1963; some photographs for 1967 and 1969) and by field work (main field work from 1959 – 1961 and some further fieldwork in 1962, 1972, 1976 and 1980). The main field work was carried out by driving along all the tracks in less accessible areas and by following a dense network of traverses (one mile apart or less) in the other areas. During the main field work, vegetation was observed along the tracks (including field glass observations on either side), transferred to 1:50 000 field maps and subsequently to aerial photographs. The additional field work was used to revise the field maps and reinterpret the aerial photographs (a quantification of the extent of revisions would provide an indication of the accuracy of the map; such quantification is not provided, unfortunately). The final maps were prepared on the scale of 1:250 000 by stereoscopic studies of the air photographs. The attempt of the maps was to plot vegetation boundaries as they were in 1960, including an interpretation of the PNV.

The legend for the four original vegetation map sheets provides a hierarchical classification of vegetation types in 18 groups, 23 subgroups, 55 classes and 217 subclasses (Appendix I and II). Polygons were digitized from the hard copy maps for all the classes. Polygons could not be digitized for subclasses since the maps only provide subclass labels but not a boundary for the area that is covered by the subclass. Areas with water or bare rock were classified as areas that are not under vegetation.

The original vegetation types were reclassified into 17 natural potential vegetation types, using various sources of information (Table 1; Kindt *et al.* 2006). Appendix I shows how the vegetation classes of the original map correspond to the vegetation type of the new map. Appendix II provides a list of the subclasses of each vegetation class. The subclass information usually provides the typical species that were encountered; this information was one of the references to compile species lists for the vegetation types (Kindt *et al.* 2007). Maps for each type are provided in Appendix III.
We use an abbreviated name for most of the 17 PNV types in the remainder of this document (Table 1).

Table 1 Characteristics of the mapped potential natural vegetation types (van Breugel et al. 2007). Vegetation types were arranged by physiognomic type (high mountain -> forest -> woodland -> savanna -> bushland, whereas types occurring under special soil conditions were listed last.

Potential natural vegetation type (shortened name)	**Total area (km2)**	**Total area rank**	**Number of patches**	**Median patch size (ha)**
Alpine (-)	93	17	15	40.9
Mountain scrubland and moorland (scrub- and moorland)	1 290	13	35	63.4
Bamboo woodland and thicket (bamboo)	3 805	11	211	46.1
Moist montane forest (MM forest)	7 879	6	143	31.2
Dry montane forest (DM forest)	17 847	1	382	41.4
Moist intermediate forest (MI forest)	8 076	5	199	33.9
Dry intermediate forest (DI forest)	3 360	12	147	54.6
Upland *Acacia* woodland, savanna and bushland (upland *Acacia*)	4 139	10	341	64.9
Broad-leaved savanna-evergreen bushland mixtures (mixtures)	311	16	73	104.4
Lowland *Acacia-Commiphora* woodland, bushland and thicket (*Acacia-Commiphora*)	6 790	7	126	29.9
Moist *Combretum*-Terminalia savanna (moist *Combretum*)	9 403	3	288	54.1
Dry *Combretum* savanna (Dry *Combretum*)	4 506	9	389	48.7
Evergreen and semi-evergreen bushland (evergreen bushland)	12 412	2	234	69.7
Semi-evergreen thicket (-)	4 606	8	307	60.3
Papyrus and swamp (swamp)	702	14	233	59.0
Open grassland areas on clay plains (open grassland)	344	15	21	114.8
Acacia and allied vegetation on soils with impeded drainage (impeded *Acacia*)	8 776	4	2 317	42.1

Trapnell and Brunt (1987) mention that identification of the PNV type (they actually use the term 'climax vegetation') was possible for most of the secondary vegetation types on the basis of fragments that contain typical species for the PNV type. These species include remnants of the climax species, pioneer species or understorey species that are associated with the climax species. Some of the residual and secondary species after selective felling of forests are provided by Trapnell (1997), together with provisional lists for each forest type that are partially based on field notes from the 1960s. A detailed list of indicator species for each vegetation type, an investigation of the accuracy of the correspondence between indicator species and vegetation type and a supplementary analysis of the correspondence between the mapped vegetation and the actual vegetation and potential vegetation (possibly by testing the map with a new series of observations) would have increased the value of the map.

Table 2 Correspondence between potential natural vegetation types (Kindt et al. 2006) and eco-climatic types defined by Trapnell and co-workers (Trapnell and Brunt 1987)

Potential natural vegetation type (shortened name)	Eco-climatic type †	Abbreviation
Alpine (no shortened name)	Mountain moorland and heath (pp)	H (pp)
Mountain scrubland and moorland (scrub- and moorland)	Mountain moorland and heath (pp)	H (pp)
Bamboo woodland and thicket (bamboo)	Mountain bamboo forest	BF
Moist montane forest (MM forest)	Eastern upper moist forest	EMU
	Western moist forest (pp)	WM (pp)
Dry montane forest (DM forest)	Montane sclerophyll forest	MS
Moist intermediate forest (MI forest)	Eastern moist intermediate forest	EMI
	Western moist forest (pp)	WM (pp)
Dry intermediate forest (DI forest)	Western Diospyros forest	WD
	Rift valley Diospyros forest	RD
	Eastern dry intermediate forest	EDI
Upland *Acacia* woodland, savanna and bushland (Upland *Acacia*)	Upland *Acacia*	UA
Broad-leaved savanna-evergreen bushland mixtures (mixtures)	(none)	(none)
Lowland *Acacia* -*Commiphora* woodland, bushland and thicket (*Acacia* -*Commiphora*)	Lowland *Acacia* and *Commiphora* bushland	LA
Moist *Combretum-Terminalia* savanna (Moist *Combretum*)	Western *Combretum* savanna	WS
Dry *Combretum* savanna (Dry *Combretum*)	Eastern *Combretum* savanna (with thicket remnants)	ES
Evergreen and semi-evergreen bushland (evergreen bushland)	Upland evergreen bushland	UB
Semi-evergreen thicket (no shortened name)	Western semi-evergreen thicket	WT
Papyrus and swamp (swamp)	(none)	(none)
Open grassland areas on clay plains (open grassland)	(none)	(none)
Acacia and allied vegetation on soils with impeded drainage (impeded *Acacia*)	(none)	(none)

† pp: pro parte, ie the eco-climatic type corresponds to several potential natural vegetation types

The name of the secondary vegetation type often enabled identification of the PNV (Appendix I and II). The position of labels for subtypes on the vegetation maps allowed reclassifying some vegetation types that only split at the subclass level (classes 2, 4 and 5). We decided to split some large polygons to increase the correspondence of the resulting polygons to the PNV. The other source of information that allowed reclassifying secondary vegetation types was provided by the eco-climatic maps that accompanied each vegetation sheet, since these eco-climatic maps reflect the PNV (Table 2). PNV types that occurred under certain soil conditions (*Papyrus* and swamp; open grassland areas on clay plains; and *Acacia* and allied vegetation on soils with impeded drainage) did not correspond to particular eco-climatic types. The *Diospyros* (-*Olea*) forests were interpreted as dry intermediate forest types, although the legend of the original maps only lists them under intermediate forests. We interpreted the Diospyros forest as a dry forest type since the WM climate type includes moist intermediate forest but no climate type categorised as western dry intermediate, since *Olea europaea* species are more typical for dry intermediate forest (Beentje [1990] describes this type as *Diospyros abyssinica – Olea europaea* forest, whereas *O. europaea* ssp. *africana* was only listed as secondary species for the dry intermediate and not for the moist intermediate forest by Trapnell [1997]; see Kindt *et al.* 2007), and since riverine forest (expected to occur within dry environments) has been described as an impoverished version of *Diospyros-Olea* forest (Beentje 1990). However, *Diospyros abyssinica* is a species of general distribution (Trapnell 1997), whereas *O. europaea* ssp. *africana* was only listed within species lists (not as secondary species) for dry montane forest, and also as secondary in moist montane forests (Trapnell 1997).

For some vegetation types that are secondary to forest it was not always possible to derive the exact vegetation type from the name (classes 2 [no distinction between moist montane and intermediate forest at the subtype level], 3, 31, 35 [no distinction between moist montane and intermediate forest at the subgroup level] and 49 [no distinction between montane and intermediate at the subtype level]) (Appendix II). To reclassify these types, we used the boundaries of the climate maps. For the western part of the map, where no distinction is made between moist montane and intermediate forest (climate type WM, for which Trapnell and Brunt [1987] mention that heavy cultivation prevented distinction between both types), we studied the distribution of other vegetation types. In case of doubt, we used the boundary of 1830 m (6000 feet) to distinguish between these two types.

2.2 Description of potential natural vegetation types with information from literature

We used two methods of finding criteria that could help to distinguish between the different vegetation types: (i) literature information from other sources than those that describe the original map; and (ii) spatial datasets to describe the range of environmental values for each type.

For the literature information, we only consulted some common references that provided a description of vegetation types for East Africa or Africa, including descriptions of vegetation types for Kenya (Beentje 1994), East Africa (Trapnell and Langdale-Brown 1972, Greenway 1973, Lind and Morrison 1974) or Africa as a whole (White 1983). We did not consult literature that only described the vegetation type for a smaller area within the map, such as a particular forest or national park. We expect that our approach will have resulted in a more general description of the various vegetation types that were encountered, and not on exceptional features of vegetation of particular areas. We obtained descriptions of PNV types based on similarity between the names of the described vegetation types. Although they formed an integral part of descriptions of vegetation types in other sources of literature, lists of typical species for various vegetation types are provided in another document (Kindt *et al.* 2007).

We looked into the public domain (Internet, literature and GIS units of ILRI and ICRAF) for interpolated surfaces layers, while limiting our search to layers with detailed information. Another important prerequisite was that sufficient information had to be available about the meaning of the maps and their descriptive classes or values. Three groups of data layers were selected for the study, including climatic, edaphic and topographic variables (Table 3).

Base climate data layers were extracted from the Almanac Characterisation Tool (ACT) 1995 database (FAO 1995a, Corbett *et al.* 1999). This database consists of interpolated 5.5 km grid surfaces which link to various tables with different climate variables based on long-term normal means for each month from FAOCLIM 1.2 (FAO 1995b) and climate coefficients from CRES, Canberra (Corbett and Kruska 1994). The number of dry months was calculated by counting the number of months with P < PET (van Breugel *et al.* 2007).

A number of data layers with derived edaphic variables that are potentially important for plant and vegetation development were extracted from the Soil and Terrain (SOTER) Database for northeastern Africa (FAO 1998). The SOTER map is a vector data layer with mapping units that provide the estimated percentage of coverage by different soil types, but not the exact location of each soil type. We therefore used the soil characteristics of the dominant soil type from the database (van Breugel *et al.* 2007).

For altitude, a corrected digital elevation model (DEM) with 90-meter grid cells was used. The Spatial Analyst toolbox in ArcGis 9.0 was used to calculate the slope based on the same DEM. Soil moisture is an important variable influencing plant distribution and species richness (Zinko *et al.* 2005, Giesler *et al.* 1998). The topographic wetness index (TWI) was originally developed to predict spatial soil moisture patterns (Schmidt and Persson 2003, but see Western *et al.* 1999 or Sørensen *et al.* 2006). TWI followed the equation of Beven and Kirkby (1979) and was calculated with the Topocrop version 1.2 extension in ArcView (Schmidt 2002). The TWI has been used in hydrological and landscape studies (Urban *et al.* 2000), to characterize biological processes (White and Running 1994), to analyze vegetation patterns (Moore *et al.* 1993, Zinko *et al.* 2005) or to assess forest site quality (Holmgren 1994).

Table 3 Interpolated surface layers used for the study of ranges in environmental conditions (van Breugel et al. 2007)

Data layer (unit) (abbreviation)	**Source**	**Resolution**
Annual precipitation (mm) (P)	ACT 1995 (FAO 1995)	5 km (grid)
Annual potential evapotranspiration (mm) (PET)	ACT 1995 (FAO 1995)	5 km (grid)
Mean minimum temperature of the coldest month (0C) (Tmin)	ACT 1995 (FAO 1995)	5 km (grid)
Number of dry months (DM)	ACT 1995 (FAO 1995)	5 km (grid)
Rootable depth (RD)	SOTER (FAO 1995)	1:1 000 000 (vector)
Cation exchange capacity (CEC)	SOTER (FAO 1995)	1:1 000 000 (vector)
Soil water pH (pH)	SOTER (FAO 1995)	1:1 000 000 (vector)
Percentage of clay	SOTER (FAO 1995)	1:1 000 000 (vector)
Percentage of sand	SOTER (FAO 1995)	1:1 000 000 (vector)
Altitude	DEM	92 m (grid)
Slope	DEM	92 m (grid)
Topographic wetness index (TWI)	DEM	92 m (grid)

All environmental and original vegetation data layers were transformed to grid data layers with a resolution of 500×500 m^2. Next, a data layer was created with random distributed points with a density of 1 sample point per 500 hectare, but with a minimum of one point per polygon. The point file was overlaid with the grid data layers and their respective grid values at location of the points were assigned to the points. These data were used to calculate the range in environmental conditions for each PNV type.

Summary plots for the range in elevation and precipitation (the two environmental descriptors that were most frequently used in the literature to characterize some vegetation types; see results) were obtained with a special function developed for the R statistical language and environment (R Development Core Team 2005) by Roeland Kindt. These plots provide information on the 10%, 25%, 75% and 90% quantile (percentile) values and the mean (see figure legends in the results section). Convex hulls were drawn around all the observations, whereby inner concentric convex hulls were constructed by excluding all the points from outer convex hulls.

3. Results

3.1 Description of potential natural vegetation types from literature information

Since the 17 retained PNV types can be re-grouped into physiognomic categories such as forest, woodland, savanna or thicket, and because such physiognomic classification schemes were used in other literature on vegetation types that we consulted, we first document the criteria that various authors listed for physiognomic types (Table 4). Not all physiognomic types were listed, since types such as semi-desert scrub were not encountered within the map.

We expect that the vegetation types of the map correspond best with the descriptions of Trapnell and Langdale-Brown (1972), since the original maps and this reference share the same principal author. The joint lower height limit of 8 m provided by Trapnell and Langdale-Brown (1972) for forests and woodlands may be less confusing than the lower limit of 10 m for forests and lower limit of 8 m for woodlands provided by other authors, although it may be difficult in reality to find vegetation types with dense canopies that have heights in between 8 and 10 m.

Trapnell and Langdale-Brown (1972) do not mention cover percentages for woodland and bushland, but their criterion for savannas indicates that they classify areas with more than 50% cover as woodland or bushland. Greenway (1973) used the same criterion. There is therefore possible confusion with other classification schemes for cover percentages of 40 - 50%. Within the Trapnell and Langdale-Brown (1972) classification, there is also a possible confusion between woodland and bushland for vegetation that is between 8 and 10 m, except if the forking habit of bushes takes precedence in classification. The other classification schemes have the limit of 8 m as a clear boundary between woodland and bushland (except if a strict interpretation would create some confusion between 7 and 8 m).

Trapnell and Langdale-Brown (1972) did not list a criterion to differentiate between savanna and grassland types, whereas the other classification schemes used limits of cover percentages for woody biomass (10%, 20%).

Table 4 Descriptions for physiognomic vegetation types provided in the literature

Type	Description	Source
High mountain vegetation	Three altitudinal belts including a bamboo zone (2400 – 3000 m), a subalpine and an alpine belt (both above 3000 m).	Trapnell and Langdale-Brown 1972
	Vegetation with specialised growth forms and specialised species such as *Lobelia* and *Senecio*, tussock grasses and sedges with xeromorphic leaves, rosette plants and sclerophyllous shrubs	White 1983
Forest	A closed stand of high trees of several stories with a dense canopy that inhibits grass growth. High forests canopies exceed 15 to 18 m with emergents up to 50 m, whereas low forest canopies have canopies of 8 to 15 m.	Trapnell and Langdale-Brown 1972
	Vegetation with interlocking crowns more than 10 m tall	Beentje 1994
	A continuous stand of trees, with canopy varying in height from 10 to 50 m or more	White 1983
	A continuous stand of trees with height of 50 m or more, with intermingling or touching crowns and often interlaced with lianas	Greenway 1973
	Trees of columnar habit often 50 m or more, with crowns touching or intermingling to form continuous canopy of complex structure. Lianas are a characteristic component, and epiphytes are characteristic of the wetter types. Most trees are evergreen, but some deciduous trees are prominent in the early successional stages.	Lind and Morrison 1974
Woodland	A mantle of trees of one or two storeys which crowns more or less touch, with height 8 – 15 and maximum 18 m.	Trapnell and Langdale-Brown 1972
	Vegetation with more than 40% cover and more than 8 m tall.	Beentje 1994
	An open stand of trees with at least 40% crown cover and height from 8 to 20 m	White 1983
	An open cover of trees without a thickly interlaced canopy and leafless for some period of the year	Greenway 1973
	Trees that are more branched than columnar and with crowns that are just touching and do not form a complex canopy. This vegetation often reaches a height of 18 m. Trees are often leafless for part of the year.	Lind and Morrison 1974
Bushland and thicket	Small trees that fork from the base with some large clear-boled trees that are between 5 – 10 m. Thickets are much closer assemblages that are often impenetrable except by game tracks and without grass cover.	Trapnell and Langdale-Brown 1972
	Vegetation with more than 40% cover with height from 3 – 7 m.	Beentje 1994
	Land that is covered by 40% or more by bushes, with height between 3 and 7 m. In thicket, the bushes are so densely interlaced as to form an impenetrable community except along tracks made by animals. If grasses contribute little to the biomass and are represented by a few annual and short-lived species, it is misleading to use 'savanna' or 'wooded grassland' even if bush cover is less than 40%.	White 1983
	Land covered with more than 50% of shrubs, giant grasses or small trees growing densely together. The bushes have no clearly defined boles and they may be from a few feet to about 10 m tall and sometimes more. Thicket is a close assemblage of bushes.	Greenway 1973
	An assemblage of woody plants with a height of less than 6 m except for occasional emergents, and a cover of not more than 20%.	Lind and Morrison 1974
Savanna or wooded grassland	Grasses that exceed 0.8 m, with woody vegetation that seldom exceeds 50% aerial cover that occasionally reaches 9 – 12 m. The trees stand in the grass instead of forming a canopy above it.	Trapnell and Langdale-Brown 1972
	Vegetation with cover of 10 – 40% and more than 6 m tall.	Beentje 1994
	Land covered with grasses and woody plant cover between 10% and 40%.	White 1983
	Land covered with grasses and with woody plants that cover less than 50% of the ground	Greenway 1973
	Grassland with scattered or grouped shrubs or trees that are conspicuous but with a cover of less than 20%. Woodland and wooded grassland should be seen as overlapping parts of a vegetational continuum.	Lind and Morrison 1974

Type	Description	Source
Grassland	Land with grass and where trees and shrubs do not cover more than 10%	Greenway 1973
	Land covered by grasses and other herbs	White 1983
	Dominated by grasses with canopy cover of trees and shrubs less than 20% (we expect that the 2% mentioned in the book is in error since 20% was used for savanna).	Lind and Morrison 1974
Swamp	Vegetation of permanently wet or flooded areas	Trapnell and Langdale-Brown 1972
	A flat area where free water accumulates for some periods of the year	Greenway 1973

The PNV types can be classified into the physiognomic types based on parts of their name (Table 5). Descriptions were found for all types with the exception of the mixtures of broadleaved savanna and evergreen bushland. As the majority of PNV types only contain one physiognomic category, this means that the physiognomic criteria provide clear boundaries for these PNV types. The listing of several PNV types for each physiognomic category (except grassland and swamp) emphasizes that non-physiognomic criteria must be used to distinguish between PNV that share the same physiognomic category (e.g., the four forest PNV types, the four savanna PNV types or the three bushland PNV types) (Table 5).

Since Beentje (1990) referenced the forest types that he differentiated to the original vegetation maps, we used information from the legend of the original map to find the correspondence between these forest types and the PNV types (see also appendix II). As Beentje (1990) also referred to the other forest classification schemes of Greenway (1973), Lind and Morrison (1974) and White (1983), we used the correspondence between Beentje (1990) and the PNV types as a link for the other classification schemes (Table 5).

The literature contained quite extensive descriptions of swamp vegetation, but since trees do not feature prominently in this vegetation (except for some mention of *Sesbania sesban* and *Acacia xanthophloea*), the descriptions were kept short in the above tables (5 and 6). Several authors (Trapnell and Langdale-Brown 1972, White 1983) list high mountain vegetation types as separate physiognomic types, including bamboo and afro-alpine physiognomic vegetation types, rather than special cases of other physiognomic types such as thickets or grasslands. Such separation allows for a better discrimination between distinctive vegetation types such as bamboo and grassland (White 1983).

Table 5 Grouping of potential natural vegetation types onto physiognomic types, with description of vegetation types summarised from the literature.

Physiognomic type	Potential natural vegetation	Vegetation type in literature	Description	Reference
High mountain vegetation	Alpine	Alpine belt	Short alpine grasses and the picturesque stands of giant *Senecio* and *Lobelia*	Trapnell and Langdale-Brown 1972
		Afro-alpine belt	A diverse vegetation type on different mountains with as only common vegetational feature that it occurs above the Ericaceous belt	White 1978
		Mixed afro-alpine communities (mapping unit 65)	Vegetation of the highest mountains of tropical Africa (3800 – 6000 m) that is characterised by giant *senecios*, giant *lobelias*, shrubby *alchemillas* and other plants of remarkable lifeform. There are no endemic genera and very few species do not occur in the Ericaceous and forest belts	White 1983
		Dendrosenecio woodland and wooded grassland	*Dendrosenecios* occur scattered in grassland on all the mountains, but woodland only occurs on the wetter mountains (Virungas and Ruwenzori) from 3500 – 4000 m.	Lind and Morrison 1974
	Mountain scrubland and moorland	Sub-alpine belt	Ericaceous belt characterised by heathers and tussock grasses, above about 3000 m	Trapnell and Langdale-Brown 1972
		Ericaceous belt	Bushland, shrubland or thicket (0.5 – 8 m) dominated by species of *Philippia* and with species of *Erica* playing an important role in the lower parts. The belt occurs from 2600-3400 to 3550-4100 m in East Africa	White 1978
		Afro-montane evergreen bushland, thicket, shrubland and secondary grassland (mapping unit 19a and 65)	Bushland and thickets (3-13 m) occur on most of the higher mountains and on the crests and summits of the smaller mountains. On wetter mountains where the ground is not very rocky and there has been protected from fire for several years, the dominants form almost impenetrable thickets. They vary greatly in floristic composition, but some members of the *Ericaceae* are almost always present. On shallow soils, shorter shrubland occurs with stunted individuals of dominant *Ericaceae* of the bushland and thicket	White 1978
		Ericaceous woodland and wooded grassland	Upland forest gives way to woodland of giant heaths and heath-like plants between 3000 – 4000 m. From 4000 - 4200 m the giant heaths diminish in size and then disappear	Lind and Morrison 1974
		Tussock grassland and moorland	The tussock grasslands may be the ultimate replacement of the ericaceous and *Dendrosenecio* woodlands as the result of burning or on the driest mountains	Lind and Morrison 1974
	Bamboo woodland and thicket	Mountain bamboo belt	Dense thickets of bamboo with a height of 10–15m and above sometimes mixed with some trees, between 2400 – 3000 m. Bamboo dies out in blocks and trees establish in the interval before regeneration.	Trapnell and Langdale-Brown 1972
		Afro-montane bamboo (mapping unit 19a)	In East Africa, *Arundinaria alpina* is mostly found between 2380 – 3000 m, but it ascends to 3200 m on Mount Kenya. It grows most vigorously on deep volcanic soils on gentle slopes that receive more than 1250 mm rainfall. Flowering is gregarious at intervals of at least 30 years.	White 1983

Physiognomic type	Potential natural vegetation	Vegetation type in literature	Description	Reference
		Arundinaria alpina forest or thicket	1800 – 3330 m and more common on the upper part. The mountain bamboo grows most vigorously and forms continuous stands where rainfall exceeds 1250 mm, where soils are deep and slopes not steep.	Lind and Morrison 1974
		Hagenia-Hypericum transition zone	In some cases (e.g., Mount Kenya and the Aberdares), there is a transition zone characterised by tree species of *Hypericum* and *Hagenia*.	Trapnell and Langdale-Brown 1972
High mountain vegetation	Bamboo woodland and thicket	*Hagenia-Hypericum* horizon	On some East African mountains (Mt. Kenya, but not Ruwenzori, Elgon or Kilimanjaro), there is a *Hagenia-Hypericum* horizon above the forest and bamboo horizons.	White 1978
		Hagenia abyssinica woodland or scrub forest (mapping unit 19a)	This type of forest characteristally form almost pure stands in the narrow and often interrupted zones between taller types of montane forest and the thickets and shrublands of the Ericaceous belt. Some stands have the structure of woodland or scrub forest.	White 1983
		Hagenia woodland	*Hagenia abyssinica* has a wide altitudinal range, but forms woodland around 3200 m until 3500 m on Mount Elgon. It often coincides with the wettest zones, but can also be found under drier conditions, and can withstand low night temperatures.	Lind and Morrison 1974
		Wetter montane forest	Generally above 1800 m, rainfall of 1400 – 2000 mm.	Trapnell and Langdale-Brown 1972
		Afro-montane rain forest (mapping unit 19a)	1200 – 2500 m, but the precise altitudinal limits vary according to the distance from the equator, sea and size and configuration of the massif. The mean rainfall lies between 1250 – 2500 mm. It differs from Guineo-Congolian rainforest in the occurrence of tree ferns (*Cyathea*), conifers (*Podocarpus*), a greater degree of bud protection and drip tips of leaves are less developed.	White 1983
	Moist montane forest	*Ocotea* forest	1600 – 2450 m, rainfall 1600 – 2450 mm.	Beentje 1990
		Ocotea-Podocarpus forest	1700 – 2400 m, rainfall above 2226 mm.	Lind and Morrison 1974
Forest		*Aningeria-Strombosia-Drypetes* forest	1600 – 2100 m, rainfall 1600 – 2450 mm. Similar to *Ocotea forest*, but slightly fewer species.	Beentje 1990
		Aningeria adolfi-friedericii forest	Wet montane forests 1524-2438 m.	Lind and Morrison 1974
		Albizia-Neoboutonia-Polyscias forest	1650 – 2250 m, rainfall 1170 – 1800 mm. A marginal variant of the *Ocotea* and *Aningeria-Strombosia-Drypetes* types.	Beentje 1990
		Drier montane forest	Generally above 1800 m, rainfall of (650) 750 – 1400 mm.	Trapnell and Langdale-Brown 1972
	Dry montane forest	Undifferentiated Afro-montane forest (mapping unit 19a)	Shorter than afro-montane rain forest and with distinctive composition. It replaces afromonantane rain forest at higher altitudes (and sometimes lower altitudes) on the wetter slopes and at comparable altitudes on the drier slopes. It usually but not always receives a lower rainfall. After fire it is sometimes replaced by almost pure stands of *Juniperus procera* or *Hagenia abyssinica*	White 1983

Physiognomic type	Potential natural vegetation	Vegetation type in literature	Description	Reference
Forest	Dry montane forest	*Juniperus procera* forest (mapping unit 19a)	It mostly occurs on the drier slopes of mountains between 1800 – 2900 m, but sometimes descends to 1000 m. Rainfall is 1000 – 1150 mm. Succulents such as *Dracaena* and *Euphorbia candelabrum* are absent. *Juniperus procera* is a strong light demander and does not regenerate in its own shade and therefore requires fires for regeneration.	White 1983
Forest	Dry montane forest	*Hagenia abyssinica* forest (mapping unit 19a)	It occurs on wetter and drier mountains between 1800 and 3400 m. The abundance is not related to moisture, but it is normally absent from afromontane rain and undifferentiated forest. It forms pure stands (9-15 m) in the narrow zone between montane forest and the Ericaceous belt. Even at high altitudes, its abundance is at least partly due to disturbance. The best-developed stands are clearly forest.	White 1983
Forest	Dry montane forest	Mixed *Podocarpus latifolius* forest (incl. *Cassipourea malosana* forest)	1150 – 2800 m, rainfall 850 – 1250 mm. Some bamboo is coming in the forest.	Beentje 1990
Forest	Dry montane forest	*Cassipourea malosana* forest	2000 – 3000 m. The drier end of the *Ocotea* forest grades into this type of forest.	Lind and Morrison 1974
Forest	Dry montane forest	*Podocarpus falcatus* forest	1800 – 2200 m, rainfall 850 – 1350 mm	Beentje 1990
Forest	Dry montane forest	*Juniperus-Nuxia-Podocarpus* forest	1950 – 3050 m, rainfall 800 – 1350 mm	Beentje 1990
Forest	Dry montane forest	*Juniperus and Juniperus-Olea* forests	1600 – 2400 m, rainfall (675) 700 – 925 mm	Beentje 1990
Forest	Dry montane forest	*Juniperus* forest	(1067) 1829 – 2896 m in the drier highland areas	Lind and Morrison 1974
Forest	Moist intermediate forest	Wetter intermediate and lowland forest	Generally below 1800 m, rainfall of 1000 – 1900 mm	Trapnell and Langdale-Brown 1972
Forest	Moist intermediate forest	Transitional rain forest (mapping unit 4)	Little has been published and only small fragments remain such as Kakamega forest (1520 – 1680 m) and forests in western Burundi (1600 – 1900 m).	White 1983
Forest	Moist intermediate forest	Tropical rain forest	1550 – 1800 m, rainfall 1700 – 2000 mm and above	Beentje 1990
Forest	Moist intermediate forest	Forests of Kakamega region	Although these forests have species in common with the Lake Victoria lowland forests, they resemble more closely the higher level forests around 1500 m of Uganda.	Lind and Morrison 1974
Forest	Moist intermediate forest	Newtonia forest	1250 – 1800 m, rainfall 1250 – 1580 mm	Beentje 1990
Forest	Moist intermediate forest	*Croton sylvaticus* – Premna maxima forest	1200 – 1850 m, rainfall 1300 mm	Beentje 1990
Forest	Dry intermediate forest	Drier intermediate and lowland forest	Generally below 1800 m, rainfall of 900 – 1000 mm	Trapnell and Langdale-Brown 1972
Forest	Dry intermediate forest	Dry transitional montane forest (mapping unit 19a)	On the drier slopes of East African mountains and uplands that rise from the Somalia-Masai plains. Only small fragments remain and there is little published information. There are some well-preserved examples near Nairobi between 1650-1800 m and rainfall around 800 mm. The main canopy is 15-18 m with emergents up to 25 m.	White 1983

Physiog-nomic type	Potential natural vegetation	Vegetation type in literature	Description	Reference
Forest	Dry intermediate forest	*Diospyros abyssinica – Olea europaea* forest	1600 – 1800 m, rainfall 1150 – 1300 mm	Beentje 1990
		Croton-Brachylaena-Calodendrum forest	1600 – 1850 (2000) m, rainfall 750 – 925 mm	Beentje 1990
		Brachylaena-Croton forest	Semideciduous forests that occur on plateaus with rainfall 875 – 1000 mm	Lind and Morrison 1974
Woodland	Upland *Acacia* woodland	(none)	(none)	(none)
	Lowland *Acacia-Commiphora* woodland	Somalia-Masai *Acacia-Commiphora* deciduous bushland and thicket	In higher rainfall areas, especially on rocky hills, the emergent trees occur closer together and are a little taller though scarcely ever more than 10 m. Greenway described this as woodland	White 1983
		Other woodland types (pp)	Closed stands in lower regions of *Acacia polycantha* ssp. *campylantha*, *A. xanthophloea* and *A. tortilis* ssp. *spirocarpa*	Trapnell and Langdale-Brown 1972
Savanna	Moist *Combretum-Terminalia* savanna	Wetter *Combretum* savanna	A small tree savanna with large-leaved species of *Terminalia*. Becomes woodland locally	Trapnell and Langdale-Brown 1972
		Guineo-Congolian secondary grassland, woodland and rainforest remnants (mapping unit 11a)	Much of the rainforest has been destroyed by cultivation and fire and occurs in a mosaic with small (usually degraded) patches of the original forest. The grassland is often 2 m or taller and contains an admixture of fire-hardy trees.	White 1983
		Combretaceous woodland and savanna	Increase in effective rainfall favours this vegetatation type to *Acacia-Themeda* savanna (upland *Acacia*). Two genera of the *Combretaceae* family, *Combretum* and *Terminalia*, are common	Lind and Morrison 1974
	Dry *Combretum* savanna	Drier *Combretum* savanna	A small tree savanna with smaller-leaved species of *Terminalia*. Becomes woodland locally	Trapnell and Langdale-Brown 1972
	Acacia and allied vegetation on soils with impeded drainage	*Acacia* savanna on floodplain, black clay, seasonally waterlogged and hardpan	Vegetation associated with special soil and drainage conditions	Trapnell and Langdale-Brown 1972
	Upland *Acacia* savanna	Higher-level *Acacia* savanna	Possible exceptions to *Acacias* that occur on special soil and drainage conditions or to *Acacia*s that are of secondary character. They have a grass layer of the *Themeda* order	Trapnell and Langdale-Brown 1972
		Acacia-Themeda wooded grassland	The greatest development of this important vegetation type is the broad belt that encircles the Kenya highlands 1200 – 1500 m with rainfall 500 – 750 mm. The species composition varies from place to place depending on soil conditions and rainfall, but *Acacia* is always the commonest tree and *Themeda triandra* the dominant grass	Lind and Morrison 1974
Bushland and thicket	Evergreen and semi-evergreen bushland	Evergreen and semi-evergreen types	Evergreen and mixed evergreen and deciduous vegetation that were once extensive in drier parts of the Kenya highlands and in some parts of the Lake Victoria basin	Trapnell and Langdale-Brown 1972
		East African evergreen and semi-evergreen bushland and thicket (mapping unit 45)	Vegetation that occurs on the drier slopes of mountains and upland areas. It often forms an ecotone between montane forest (*Juniperus*) and *Acacia-Commiphora* bushland and thicket.	White 1983
	Upland *Acacia* bushland	(no reference)	(no reference)	(no reference)
	Lowland *Acacia-Commiphora* bushland and thicket	*Commiphora* bushlands	Vegetation with thicket density but many of the grotesque angularly-branched *Commiphora* species. Only some areas were well studied and the genus requires revision	Trapnell and Langdale-Brown 1972

Physiognomic type	Potential natural vegetation	Vegetation type in literature	Description	Reference
Bushland and thicket	Lowland *Acacia-Commiphora* bushland and thicket	Somalia-Masai *Acacia-Commiphora* deciduous bushland and thicket (mapping unit 42, some secondary savanna)	The climax over the greater part of the Somalia-Masai regional centre of endemism (IV), characterised by dense bushland (3-5 m) with scattered emergent trees (9 m). Locally it is impenetrable and forms thickets. Only a few species have well-defined trunks and most species are branched near the base. Succulents occur more scattered but are rarely plentiful.	White 1983
		Bushland of Tsavo and Amboseli	The rainfall is around 750 mm. The ground cover is made up mainly of woody shrubs that are often succulent or thorny and often have small deciduous leaves.	Lind and Morrison 1974
	Semi-evergreen thicket	Evergreen and semi-evergreen bushland and thicket and derived communities (mapping unit 45)	The climax vegetation of large parts of the Lake Victoria regional mosaic. Today only small islands remain and most of the landscape is of lightly wooded *Acacia* grassland. The thickets are established because lianes that smother the crowns of *Acacia* trees suppress the regeneration of *Acacia* and the vigour of the grass layer.	White 1983
Grassland	Open grassland areas on clay plains	Pure natural grasslands (pp)	Pure natural grasslands which exist in the absence of fire that are confined conditions of impeded drainage, such as vlei, mbuga, dambo, flood plains and certain black clay plains.	Trapnell and Langdale-Brown 1972
		Somalia-Masai edaphic grassland (unit 42, 45)	Seasonally waterlogged grassland has a very uneven distribution, with little information for Kenya. The glades also occur on non-cracking calcimorphic hardpan soils, where the dominants are dwarf grasses.	White 1983
Swamp	Papyrus and swamp	Swamp vegetation of permantly wet or flooded areas (64)	Vegetation types that are dominated by *Cyperus papyrus* and other *Cyperaceae*	Trapnell and Langdale-Brown 1972
		Halophytic vegetation (76)	On the eastern part of tropical Africa, halophytic vegetation occurs in most of the lake basins in the Eastern Rift, principally Lakes Turkana, Bogoria, Elementeita, Magadi, Natron, Manyara, Eyasi and Rukwa. Lakes Baringo and Naivasha are much less saline, probably because of subterranean outlets.	White 1983
		Herbaceous fresh-water swamp	Most of the shallower lakes outside the Guineo-Congolian region have a wide belt of reed-swamp for which *Cyperus papyrus* is the main constituent	White 1983

3.2 Description of potential natural vegetation types with information from spatial datasets

In this section, we provide a description of the typical environmental conditions for each vegetation types (Tables 6 and 7). Large overlaps can be observed between the various PNV types (indicated by overlaps between minimum and maximum values and by the convex hulls), often including overlaps between the 10% - 90% quantile ranges (Tables 6 and 7, Figures 1 – 5).

Table 6 Range in altitude and climatic variables for the 17 potential natural vegetation types. Percentages indicate the quantiles, e.g. 10% = 3777 means that 10% of observations are smaller than 3777. Potential natural vegetation types are ordered by mean altitude, but forest types were grouped together.

Variable	Vegetation	mean	min	max	10%	25%	50%	75%	90%
Altitude	alpine	4029.0	3737	4341	3777	3862	4027	4162	4292
	scrub- and moorland	3306.0	1817	4104	3029	3115	3281	3493	3645
	bamboo	2686.0	2197	3471	2363	2491	2640	2851	3099
	DM forest	2324.7	1636	3329	1987	2099	2305	2520	2709
	MM forest	2015.0	1414	2757	1791	1886	1981	2129	2289
	DI forest	1745.0	1284	2249	1485	1562	1767	1908	2005
	MI forest	1580.0	733	2161	1246	1369	1574	1779	1952
	evergreen bushland	1876.0	1176	2335	1698	1788	1876	1967	2066
	mixtures	1776.0	1130	2252	1362	1677	1837	1933	2017
	impeded *Acacia*	1670.0	729	3580	1149	1269	1568	1945	2354
	upland *Acacia*	1574.6	860	2117	1290	1442	1581	1718	1850
	swamp	1570.0	955	2705	1140	1145	1524	1899	2089
	moist *Combretum*	1526.0	1128	2065	1280	1354	1478	1687	1853
	open grassland	1418.0	978	1786	1151	1333	1358	1449	1765
	dry *Combretum*	1306.0	611	2120	1055	1137	1256	1464	1674
	semi-evergreen thicket	1250.0	712	1981	1103	1177	1236	1330	1455
	Acacia-Commiphora	1066.0	489	1651	734	958	1109	1220	1299
Precipitation	alpine	1586.6	1354	1722	1476	1483	1564	1674	1680
	scrub- and moorland	1414.1	710	1722	1209	1327	1447	1534	1600
	bamboo	1226.0	534	1621	1024	1128	1243	1336	1408
	DM forest	981.9	534	1562	711	813	988	1135	1238
	MM forest	1334.3	688	1801	1055	1171	1336	1486	1608
	DI forest	1190.0	688	1595	902	1006	1246	1337	1447
	MI forest	1419.0	602	1864	1102	1334	1445	1560	1639
	evergreen bushland	822.2	516	1482	587	649	745	1003	1124
	mixtures	867.8	562	1257	649	729	873	993	1059
	impeded *Acacia*	1086.3	508	1801	740	864	1102	1279	1408
	upland *Acacia*	833.5	502	1316	627	705	827	967	1025
	swamp	1229.5	532	1801	811	1061	1261	1358	1561
	moist *Combretum*	1325.4	1001	1696	1084	1188	1360	1440	1521
	Open grassland	1013.1	619	1262	694	1063	1094	1110	1122
	dry *Combretum*	863.0	544	1243	741	790	851	943	1004
	semi-evergreen thicket	1133.5	562	1728	788	1029	1153	1313	1369
	Acacia-Commiphora	754.0	541	1223	600	675	769	821	869
PET	alpine	991.9	888	1150	914	937	941	1030	1068
	scrub- and moorland	1157.4	888	1505	977	1053	1142	1240	1369
	bamboo	1246.0	987	1565	1140	1196	1238	1286	1394
	DM forest	1316.0	1030	1814	1196	1241	1303	1384	1450

Variable	Vegetation	mean	min	max	10%	25%	50%	75%	90%
	MM forest	1394.2	1197	1664	1297	1333	1382	1449	1521
	DI forest	1445.0	1197	1837	1366	1404	1449	1478	1519
	MI forest	1531.0	1309	1839	1429	1465	1532	1601	1629
	evergreen bushland	1423.5	1169	1740	1304	1380	1430	1480	1515
	mixtures	1556.3	1197	1837	1389	1440	1557	1615	1783
	impeded *Acacia*	1479.7	962	1848	1264	1398	1491	1592	1626
	upland *Acacia*	1490.1	1230	1857	1362	1401	1498	1559	1617
	swamp	1502.4	1179	1796	1358	1408	1519	1595	1610
	moist *Combretum*	1543.5	1319	1643	1450	1502	1549	1604	1624
	Open grassland	1523.6	1298	1730	1364	1538	1541	1543	1586
	dry *Combretum*	1624.3	1321	1873	1505	1574	1627	1682	1731
	semi-evergreen thicket	1573.2	1314	1862	1466	1522	1566	1596	1727
	Acacia-Commiphora	1692.3	1396	1879	1587	1619	1675	1764	1837
T_{min}	alpine	0.3	-2.6	4.2	-1.8	-1.0	-1.0	1.8	2.1
	scrub- and moorland	3.5	-2.6	12.0	-0.3	1.6	3.7	5.5	6.6
	bamboo	6.6	0.6	12.3	4.1	5.5	7.0	7.6	8.5
	DM forest	7.6	1.8	16.9	5.8	6.6	7.5	8.4	9.9
	MM forest	9.8	5.1	14.1	8.2	9.0	9.8	10.6	11.6
	DI forest	10.8	5.9	17.5	8.7	10.0	10.9	12.0	12.6
	MI forest	12.5	9.1	17.2	10.8	11.4	12.4	13.5	14.8
	evergreen bushland	8.9	5.9	15.2	7.4	7.9	8.6	9.7	10.6
	mixtures	11.7	6.6	17.5	8.5	9.9	11.4	12.5	16.6
	impeded *Acacia*	11.5	-0.7	17.6	7.2	9.4	11.9	13.8	14.9
	upland *Acacia*	10.9	6.4	17.7	8.4	9.4	10.8	12.1	13.6
	swamp	12.3	5.8	16.5	8.3	10.3	12.7	15.0	15.5
	moist *Combretum*	13.0	8.5	15.4	10.8	12.1	13.1	14.1	14.6
	Open grassland	13.3	7.6	15.5	8.4	13.9	14.2	14.5	14.8
	dry *Combretum*	13.4	6.6	18.4	11.5	12.6	13.6	14.3	15.1
	semi-evergreen thicket	14.2	6.6	18.0	11.9	13.8	14.7	15.0	15.5
	Acacia-Commiphora	*14.7*	8.3	18.6	12.6	13.5	14.4	16.1	17.4
Dry months	alpine	3.0	2	6	2	2	3	3	4
	scrub- and moorland	4.9	2	10	3	3	5	6	8
	bamboo	6.9	3	12	5	6	7	8	9
	DM forest	8.6	3	12	7	7	8	10	10
	MM forest	7.1	2	12	4	6	8	9	9
	DI forest	7.9	4	12	6	7	8	9	10
	MI forest	7.5	2	10	5	6	8	9	10
	evergreen bushland	10.2	5	12	8	9	10	12	12
	mixtures	9.9	7	12	8	8	10	12	12
	impeded *Acacia*	8.8	2	12	7	8	9	10	10
	upland *Acacia*	9.8	7	12	8	9	10	10	12

Variable	Vegetation	mean	min	max	10%	25%	50%	75%	90%
	swamp	8.3	2	12	4	7	9	10	10
	moist *Combretum*	8.1	4	10	6	7	8	10	10
	Open grassland	10.4	9	12	10	10	10	10	12
	dry *Combretum*	9.8	7	12	9	9	10	10	10
	semi-evergreen thicket	9.6	2	12	8	9	10	10	10
	Acacia-Commiphora	10.5	8	12	10	10	10	11	12

Besides the wide range in overlap of altitude and precipitation between many PNV types, Figure 1 confirms the position of mixtures in between dry *Combretum* and evergreen bushland, although the conditions are more similar to upland *Acacia* than dry *Combretum*.

We focused on an investigation of altitude and precipitation and on differences between PNV types of the same physiognomic category as more sophisticated investigations in an accompanying report explored the relationship between environmental characteristics and PNV types in greater detail (van Breugel *et al.* 2007). We looked at overlaps between 10% - 90% quantile ranges and in a few exceptions at overlaps of 25% - 75% quantile ranges (as indicated). The main purpose of the information provided (tables 5 and 6) is to document the observed range in environmental characteristics that can be observed within the boundaries of the new map so that this new map can be used as a method of summarising environmental conditions.

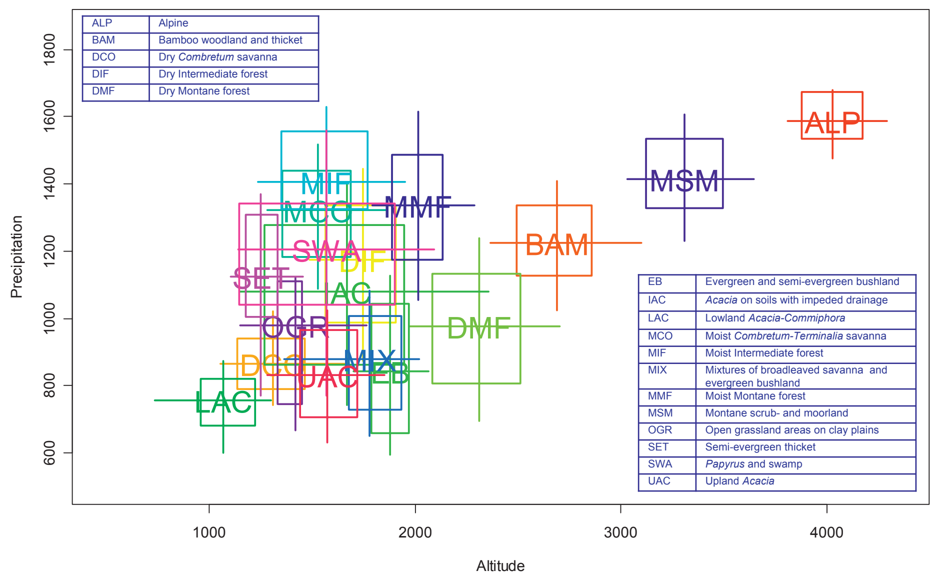


Fig. 1 Range in altitude and rainfall for the 17 potential natural vegetation types. Segments are aligned on the mean of the other variable, the length of the segment shows 10% - 90% quantiles and the width of the box the 25%-75% quantiles.

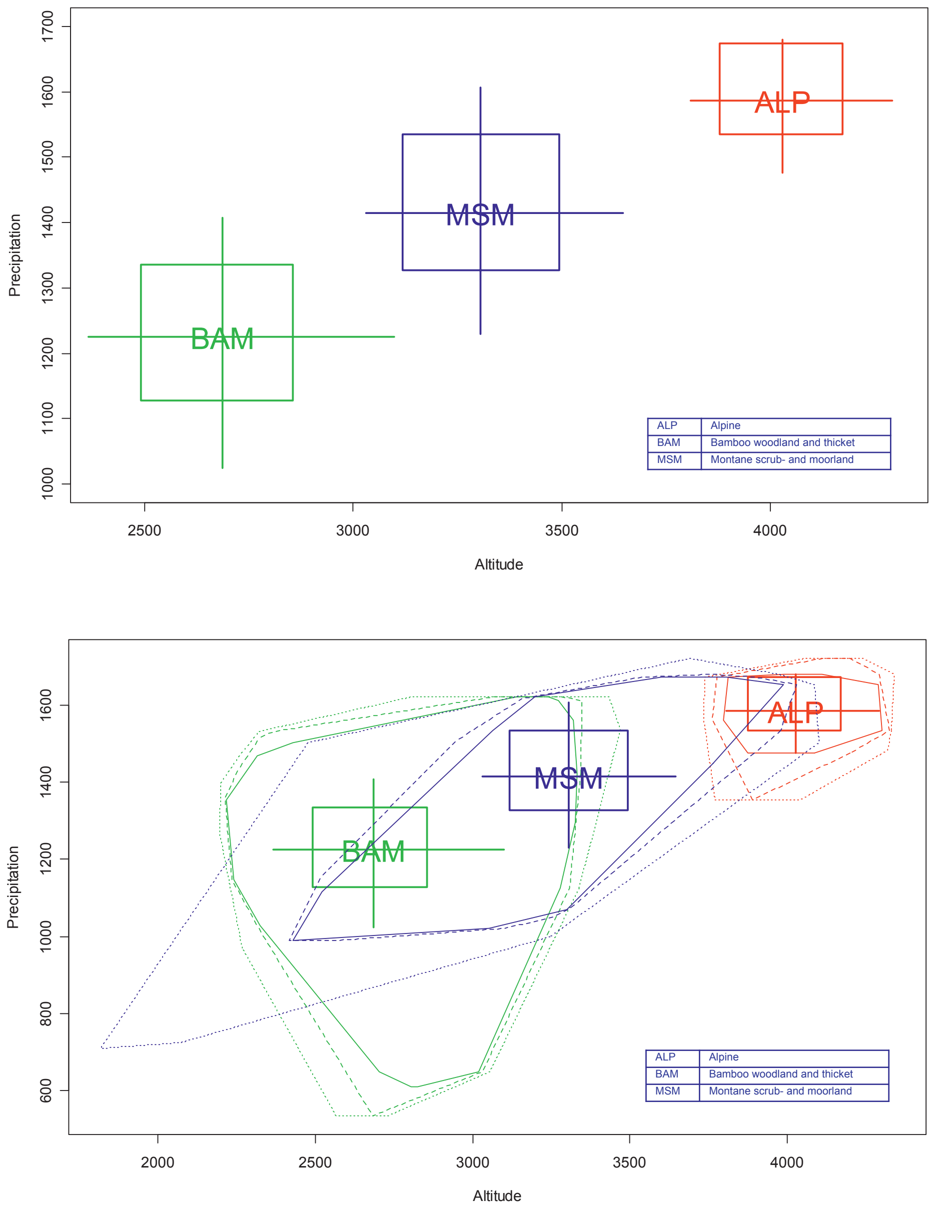


Fig. 2 Range in altitude and rainfall for the three high mountain potential natural vegetation types. Segments are aligned on the mean of the other variable, the length of the segment shows 10% - 90% quantiles and the width of the box the 25%-75% quantiles. Top: without concentric convex hulls, bottom: with concentric convex hulls around all points

Within the high mountain vegetation types, there is a clear differentiation between alpine (altitude > 3777 m) and scrub- and moorland (altitude < 3645 m) and a small overlap between bamboo (altitude < 3099 m) and scrub- and moorland (altitude > 3029 m). The altitudinal limits correspond well with the literature information of 3800 m for mixed afro-alpine communities (White 1983; Table 4) and 2380 – 3200 m (White 1983, Table 4) or 2400 – 3000 m for bamboo (Trapnell and Langdale-Brown 1972, Table 4). Overlaps in rainfall are considerably larger.

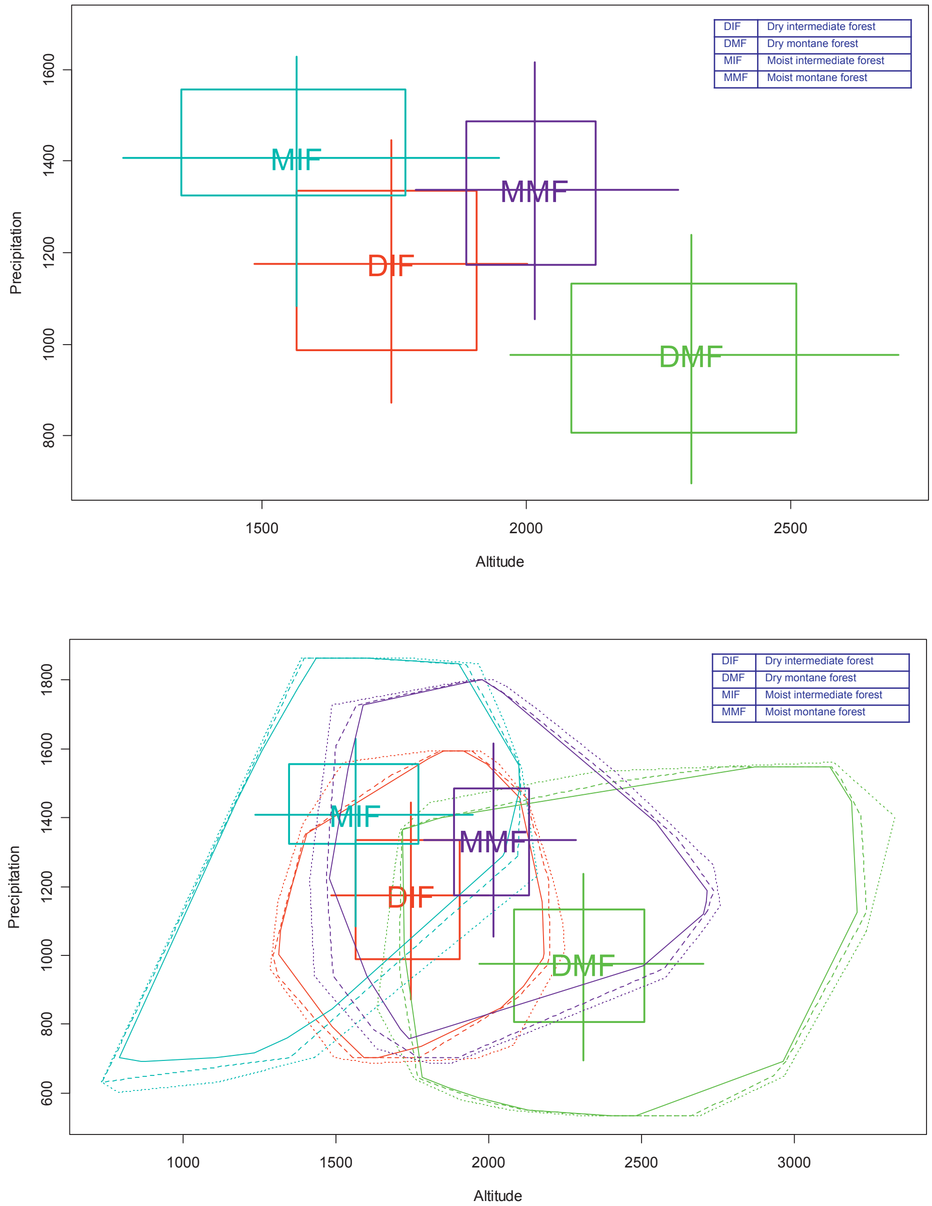
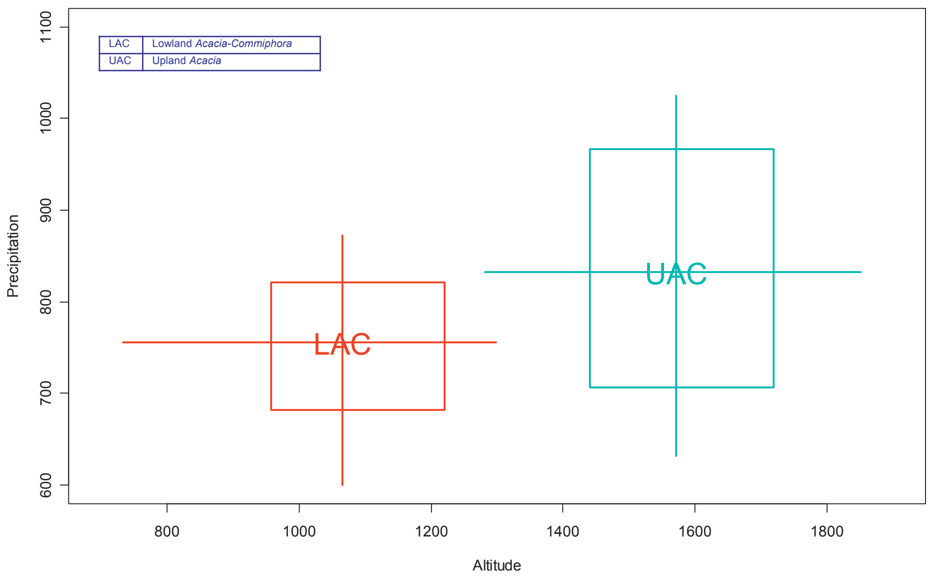


Fig. 3 Range in altitude and rainfall for the four forest potential natural vegetation types. Segments are aligned on the mean of the other variable, the length of the segment shows 10% - 90% quantiles and the width of the box the 25%-75% quantiles. Top: without concentric convex hulls, bottom: with concentric convex hulls around all points

Within forest PNV types, although montane forests are generally located in higher locations and moist forests have larger precipitation for the majority of observations, differences between forest types are not clear for the 10% - 90% quantile ranges: the only clear difference can be observed for altitude of DM forest (> 1987 m) and MI forest (altitude < 1952 m) (Table 6, Figure 3). Differences become somewhat clearer when using 25% - 75% quantile ranges and combining altitude and precipitation: boundaries are for DM forest > 2099 m and < 1135 mm, for MM forest they are > 1886 m and > 1171 mm, for DI forest they are < 2005 m and < 1337 mm and for MI forest they are < 1952 m and > 1334 mm. Besides showing the considerable overlap in environmental conditions, these findings show that the altitudinal bound-



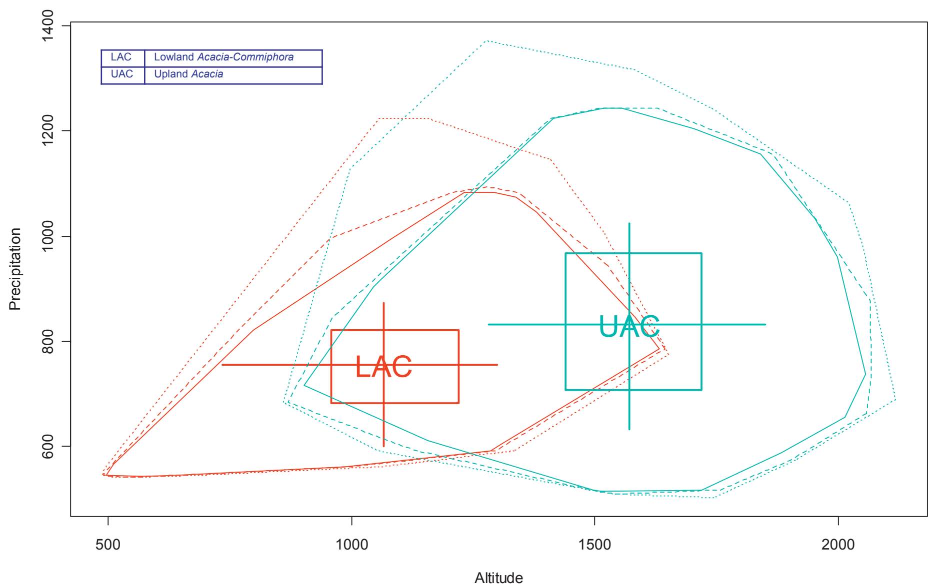


Fig. 4 Range in altitude and rainfall for the two woodland potential natural vegetation types. Segments are aligned on the mean of the other variable, the length of the segment shows 10% - 90% quantiles and the width of the box the 25%-75% quantiles. Top: without concentric convex hulls, bottom: with concentric convex hulls around all points

ary reported in the literature of 1800 m (Trapnell and Langdale-Brown 1972, Table 5) applies to montane forests, but that many sections of intermediate forests are also above 1800 m. Likewise, the findings support the precipitation boundary of 1400 mm that was reported in the literature for dry forests (Trapnell and Langdale-Brown 1972, Table 5), although a considerable section of MM forest is drier than 1400 mm.

For woodland types, there is a clear difference in altitude between upland *Acacia* (altitude > 1290 m) and lowland *Acacia-Commiphora* (altitude < 1299 m), whereas the overlap in rainfall was large. The altitude boundary approximates the limit provided in the literature for upland *Acacia* savanna (another

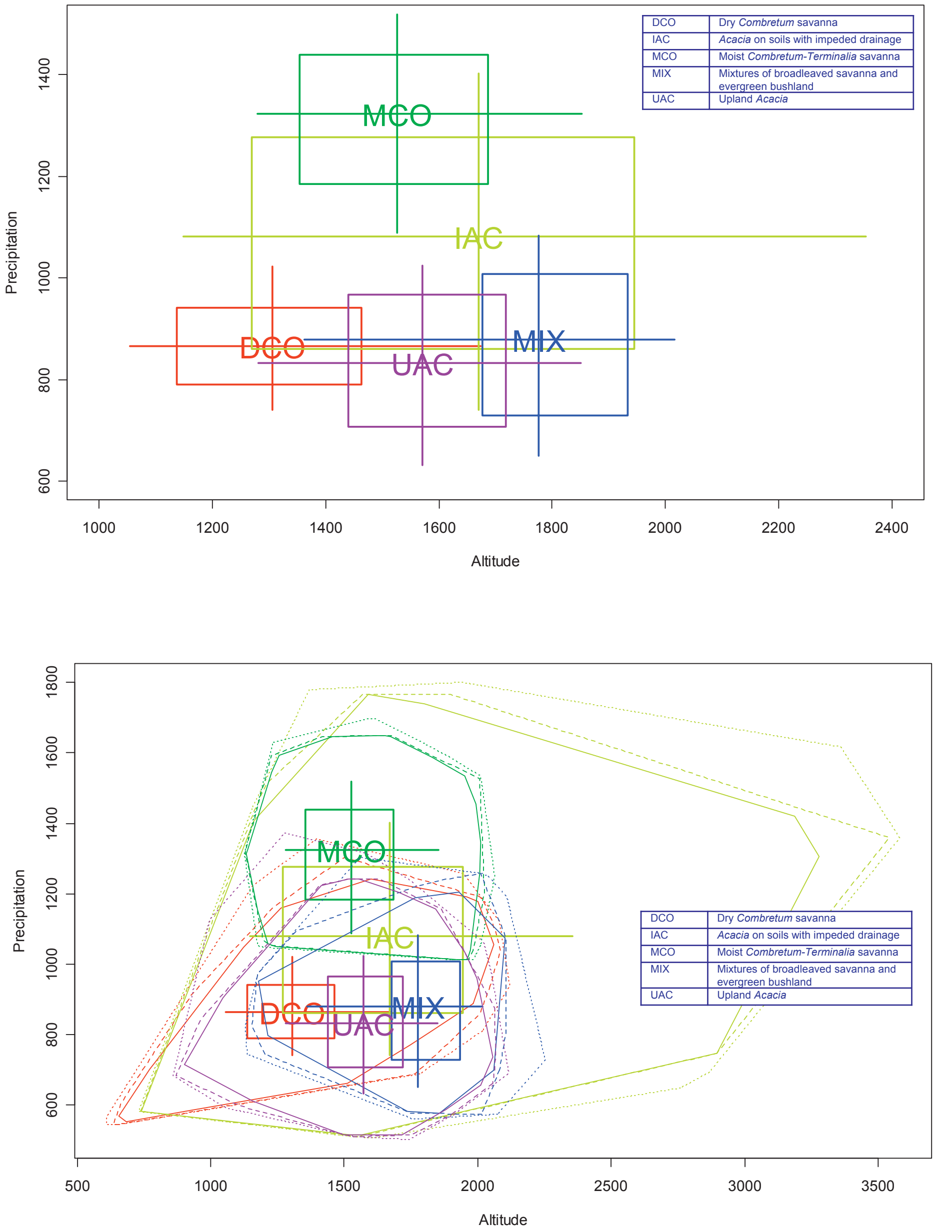
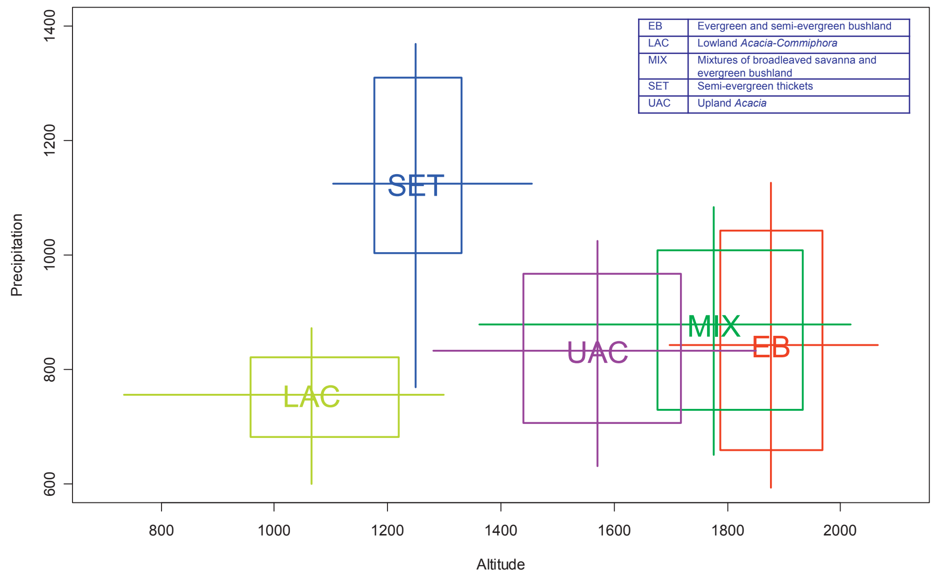


Fig. 5 Range in altitude and rainfall for the five savanna potential natural vegetation types. Segments are aligned on the mean of the other variable, the length of the segment shows 10% - 90% quantiles and the width of the box the 25%-75% quantiles. Top: without concentric convex hulls, bottom: with concentric convex hulls around all points

physiognomic category of the same PNV type) of 1200 m (Lind and Morrison 1974), although the PNV was encountered under a larger altitudinal range (1290 – 1850 m) than these authors mentioned (1200 – 1500 m) (maybe the boundary of 1500 m is related to a boundary between upland *Acacia* woodland and upland *Acacia* savanna).

For the savanna types, the impeded *Acacia* occurs under a very wide range of altitude and rainfall conditions, which provides support for the special soil conditions under which this type occurs that take precedence on climatic conditions (Table 6, Figure 5). A clear difference in precipitation can be observed between moist *Combretum* (> 1084 mm) and the other savanna types (all < 1059 mm or less), except for the impeded *Acacia*. There are



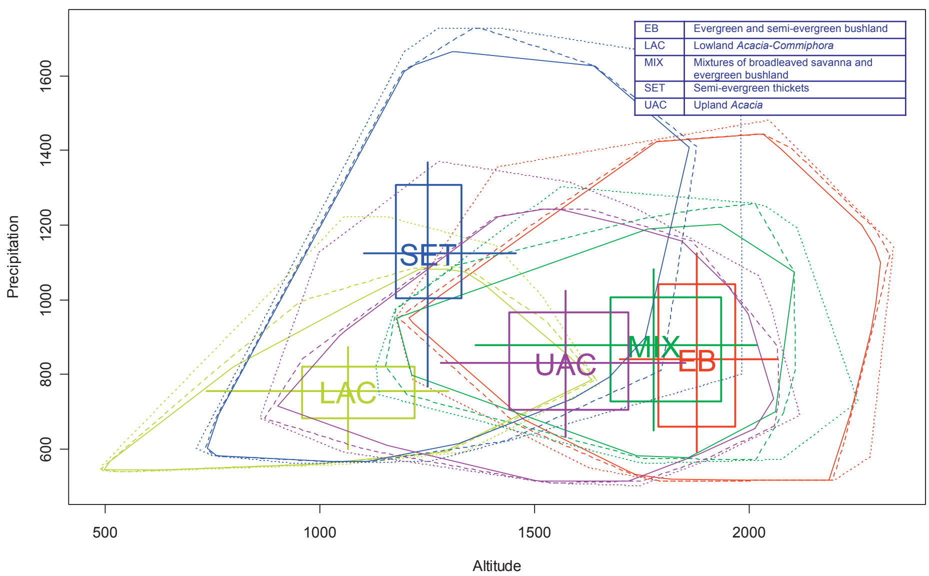


Fig. 6 Range in altitude and rainfall for the five bushland or thicket potential natural vegetation types. Segments are aligned on the mean of the other variable, the length of the segment shows 10% - 90% quantiles and the width of the box the 25%-75% quantiles. Top: without concentric convex hulls, bottom: with concentric convex hulls around all points

considerable overlaps in rainfall and altitude between dry *Combretum*, upland *Acacia* and mixtures, with only differences within 25% - 75% quantile ranges for altitude in between dry *Combretum* (< 1464 m) on the one hand and upland *Acacia* (> 1442 m) and mixtures (> 1677 m) on the other hand. The upland *Acacia* occurs under a wider range of altitude than the 1200 – 1500 m reported by Lind and Morrison (1974, Table 4, also see above), although the lower limit reported in the literature seems to be respected. The rainfall conditions of this PNV type are generally higher than the 500 – 750 mm reported by Lind and Morrison (1974, Table 4).

Acacia-Commiphora occurs in areas that are generally lower (< 1299 m) (but not always drier) than upland *Acacia* (> 1290 m) and evergreen bushland

(> 1698 m), and in areas that are generally drier (< 869 mm) (but not always higher) than semi-evergreen thicket (> 788 mm) (Table 5, Figure 6). Although a similarity in their names suggests otherwise, the evergreen bushland (> 1698 m) can be clearly differentiated from the semi-evergreen thickets (< 1455 m). There is a considerable overlap in altitude and rainfall in between upland *Acacia* and evergreen bushland, with only clear differences for the 25% - 75% quantile ranges for altitude with upland *Acacia* < 1718 m and evergreen bushland > 1788 m. The mixtures clearly occur in areas with similar conditions as evergreen bushland, whereas also containing areas of lower altitude but similar precipitation that are more typical for dry *Combretum* (figures 5 and 6).

Table 7 Range in topographic and edaphic variables for the 17 potential natural vegetation types. Percentages indicate the quantiles, e.g. 10% = 6.8 means that 10% of observations are smaller than 6.8. Potential natural vegetation types are ordered by mean altitude, but forest types were grouped together.

Variable	Vegetation	mean	min	max	10%	25%	50%	75%	90%
Slope	alpine	14.5	2.5	30.9	6.8	9.9	13.9	18.4	21.9
	scrub- and moorland	11.2	0.0	54.9	3.1	5.5	9.7	14.6	20.6
	bamboo	10.3	0.3	42.7	3.4	5.8	8.7	13.5	18.8
	DM forest	7.3	0.0	42.0	1.8	3.1	5.6	9.8	15.5
	MM forest	8.7	0.0	52.2	2.7	4.5	7.3	11.3	16.6
	DI forest	6.1	0.0	41.3	1.3	2.2	3.7	6.8	13.6
	MI forest	5.3	0.0	33.5	1.4	2.5	4.3	6.7	10.6
	evergreen bushland	3.5	0.0	43.2	0.7	1.1	1.9	3.5	8.0
	mixtures	15.8	0.7	40.7	1.6	5.0	12.6	24.7	33.7
	impeded *Acacia*	2.0	0.0	18.5	0.4	0.9	1.6	2.6	3.8
	upland *Acacia*	4.1	0.0	45.7	0.7	1.2	2.2	4.4	9.5
	swamp	1.9	0.0	13.3	0.3	0.6	1.1	2.4	4.4
	moist *Combretum*	4.2	0.0	30.3	1.3	2.0	3.1	4.9	7.9
	Open grassland	1.9	0.0	11.9	0.6	0.7	1.4	2.2	3.2
	dry *Combretum*	5.0	0.0	36.0	1.0	1.7	3.1	5.8	11.3
	semi-evergreen thicket	6.7	0.0	38.3	1.1	2.0	3.5	8.5	18.8
	Acacia-Commiphora	*4.0*	0.0	35.2	0.9	1.6	2.7	4.4	8.1
TWI	alpine	4.2	3.5	5.0	3.7	3.9	4.2	4.4	4.8
	scrub- and moorland	4.6	3.1	6.8	3.8	4.2	4.6	5.0	5.6
	bamboo	4.7	2.9	6.7	3.9	4.3	4.7	5.0	5.3
	DM forest	5.1	2.9	7.7	4.1	4.6	5.1	5.6	6.1
	MM forest	4.8	2.9	7.1	4.0	4.4	4.8	5.2	5.6
	DI forest	5.4	3.0	8.0	4.1	4.9	5.5	6.0	6.5
	MI forest	5.4	3.3	8.1	4.5	5.0	5.4	5.8	6.2
	evergreen bushland	6.1	2.7	8.8	4.7	5.6	6.3	6.8	7.1
	mixtures	4.4	2.8	8.1	3.1	3.6	4.3	5.1	5.9
	impeded *Acacia*	6.5	4.1	8.4	5.7	6.1	6.5	7.0	7.3
	upland *Acacia*	6.0	3.0	9.0	4.8	5.5	6.1	6.7	7.1
	swamp	6.8	4.7	8.4	5.7	6.2	7.0	7.3	7.6
	moist *Combretum*	5.6	3.2	7.6	4.7	5.2	5.7	6.1	6.5
	Open grassland	6.6	4.9	8.1	5.7	6.2	6.6	7.0	7.3
	dry *Combretum*	5.6	3.1	7.6	4.4	5.2	5.7	6.2	6.6
	semi-evergreen thicket	5.4	2.8	8.0	3.8	4.6	5.6	6.2	6.7
	Acacia-Commiphora	5.9	3.1	8.3	4.8	5.4	5.9	6.5	6.9
RD	alpine	6.0	6	6	6	6	6	6	6
	scrub- and moorland	7.8	5	20	5	6	6	10	17
	bamboo	11.3	5	22	5	5	10	15	20
	DM forest	14.2	2	25	8	10	15	20	20
	MM forest	15.2	2	30	5	10	15	20	20
	DI forest	13.8	2	25	5	8	15	20	20
	MI forest	14.7	2	30	8	10	15	20	20
	evergreen bushland	13.7	2	25	8	10	10	20	20

Variable	Vegetation	mean	min	max	10%	25%	50%	75%	90%
	mixtures	12.6	5	20	8	8	10	17	20
	impeded *Acacia*	15.0	2	40	10	10	15	20	22
	upland *Acacia*	14.7	2	30	8	10	12	20	20
	swamp	13.8	4	30	8	10	11	20	20
	moist *Combretum*	13.0	2	30	6	10	12	16	20
	Open grassland	12.2	5	20	10	10	11	11	20
	dry *Combretum*	12.7	2	25	8	10	10	20	20
	semi-evergreen thicket	12.6	2	30	8	10	10	15	20
	Acacia-Commiphora	13.5	4	30	8	10	10	20	20
CEC	alpine	150.0	150	150	150	150	150	150	150
	scrub- and moorland	194.9	100	961	150	150	150	200	252
	bamboo	251.6	0	961	200	200	226	332	380
	DM forest	264.7	0	1883	100	200	263	332	380
	MM forest	236.0	0	961	91	200	226	335	340
	DI forest	211.9	0	1883	0	100	200	226	330
	MI forest	177.2	0	575	8	81	200	226	335
	evergreen bushland	324.7	0	1883	146	173	266	350	434
	mixtures	346.1	100	1883	101	140	263	332	961
	impeded *Acacia*	202.6	0	1883	0	100	190	282	400
	upland *Acacia*	592.8	0	1883	140	150	300	650	1883
	swamp	189.1	0	565	0	22	173	292	400
	moist *Combretum*	125.7	0	575	8	40	96	193	240
	Open grassland	373.6	0	1883	100	170	295	295	565
	dry *Combretum*	253.0	0	1883	0	146	190	200	515
	semi-evergreen thicket	220.9	0	1883	8	60	150	295	315
	Acacia-Commiphora	381.3	0	1883	118	150	190	233	1883
pH	alpine	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
	scrub- and moorland	4.8	4.5	7.5	4.5	4.5	4.5	5.0	5.3
	bamboo	5.4	4.5	7.5	4.5	5.0	5.0	6.0	6.5
	DM forest	5.9	2.5	8.3	5.0	5.5	5.8	6.5	7.0
	MM forest	5.2	4.5	8.1	4.5	4.5	5.1	5.5	6.5
	DI forest	5.7	4.5	8.3	5.0	5.4	5.5	6.0	6.5
	MI forest	5.4	4.5	7.5	5.0	5.1	5.5	5.5	5.9
	evergreen bushland	6.3	2.5	8.5	5.1	5.8	6.1	7.0	7.6
	mixtures	6.4	5.0	8.3	5.3	5.6	6.3	6.6	8.1
	impeded *Acacia*	6.0	2.5	9.0	5.1	5.3	5.8	6.5	7.5
	upland *Acacia*	6.7	2.5	8.8	5.5	6.0	7.0	8.0	8.0
	swamp	6.2	4.5	8.5	5.1	5.4	5.9	7.0	8.0
	moist *Combretum*	5.5	4.5	8.3	5.0	5.1	5.4	5.8	6.0
	Open grassland	6.4	5.4	8.5	5.5	5.8	5.8	6.1	8.5
	dry *Combretum*	6.1	5.0	8.3	5.5	5.9	6.0	6.1	7.0
	semi-evergreen thicket	6.0	4.5	9.0	5.1	5.5	5.9	6.4	8.0
	Acacia-Commiphora	6.4	5.0	8.8	5.0	5.9	6.0	7.5	8.0
% Clay	alpine	31.3	30	35	30	30	30	30	35
	scrub- and moorland	35.1	20	70	25	30	35	35	50
	bamboo	51.3	20	70	35	50	50	70	70
	DM forest	54.2	0	70	30	47	57	70	70
	MM forest	61.6	0	70	35	50	70	70	70
	DI forest	58.7	0	70	35	45	70	70	70
	MI forest	61.4	25	70	35	50	70	70	70
	evergreen bushland	52.0	0	70	25	35	52	70	70
	mixtures	47.0	25	70	25	27	47	70	70
	impeded *Acacia*	62.4	0	70	45	57	70	70	70
	upland *Acacia*	45.4	0	70	20	30	50	70	70
	swamp	61.0	22	70	35	50	70	70	70
	moist *Combretum*	60.0	0	70	35	57	70	70	70
	Open grassland	50.3	0	70	35	50	50	50	70
	dry *Combretum*	56.3	15	70	35	47	57	70	70
	semi-evergreen thicket	52.5	15	70	25	35	50	70	70
	Acacia-Commiphora	47.9	15	70	27	37	50	57	70
% Sand	alpine	42.4	35	45	35	35	45	45	45
	scrub- and moorland	38.4	18	60	25	35	35	45	45
	bamboo	26.3	10	60	18	18	25	33	35

Variable	Vegetation	mean	min	max	10%	25%	50%	75%	90%
	DM forest	27.7	10	100	18	18	25	35	45
	MM forest	21.5	10	88	18	18	18	25	33
	DI forest	27.6	10	100	18	18	18	35	55
	MI forest	24.1	11	60	18	18	18	33	35
	evergreen bushland	30.2	10	100	18	18	18	45	60
	mixtures	36.3	18	60	18	18	35	58	60
	impeded *Acacia*	23.8	10	88	18	18	18	33	36
	upland *Acacia*	33.1	10	100	18	18	25	45	58
	swamp	23.4	10	60	18	18	18	18	48
	moist *Combretum*	25.9	18	88	18	18	18	33	35
	Open grassland	24.7	10	100	10	18	25	25	25
	dry *Combretum*	29.1	18	70	18	18	33	36	48
	semi-evergreen thicket	29.9	11	70	18	18	25	36	60
	Acacia-Commiphora	35.8	18	70	18	33	33	48	48

PNV types overlap much for the edaphic and topographic variables (Table 7). For example, alpine vegetation is the only PNV type that does not overlap its range for clay percentages with impeded *Acacia* (the latter type has the highest range for this soil variable). For pH, there are only three PNV types that always have larger values than alpine and mountain scrub vegetation. The topographic wetness index identified impeded *Acacia*, open grassland and swamp as areas with largest values (thus providing some evidence against particular soil types such as vertisols), but the only PNV types for which there was no overlap was MM forest, bamboo, mountain scrub and alpine vegetation. Swamp, impeded *Acacia* and open grassland were also identified as the areas with smallest slopes, although only alpine vegetation had ranges that were always larger than any of these PNV types.

4. Discussion

4.1 Characterization of potential natural vegetation types

Despite the fact that the documentation of the map provided little discussion of how the vegetation types could be differentiated, it was possible to obtain extensive descriptions from the literature on vegetation types for East Africa or entire Africa. The literature provided clear criteria that allow differentiating between physiognomic categories, but not always between PNV types of the same physiognomic category. Criteria of rainfall and altitude were provided in the literature for the high mountain and forest PNV types, altitude was mentioned as a criterion for upland *Acacia* and special soil conditions were provided for impeded *Acacia*, open grasslands and swamps. No such criteria were provided for moist and dry *Combretum* or for evergreen and semi-evergreen bushland and semi-evergreen thickets. These are PNV types that only occasionally border each other on the map, however, so another way by which these types can be distinguished is by the general area in which they occur (Appendix III).

We often found large overlaps in environmental conditions, although in some cases clear differences were observed as in between upland *Acacia* and lowland *Acacia-Commiphora* or in between high mountain vegetation types. Although we found a reasonable correspondence for altitudinal and precipitation limits between the literature and our investigations, the overlaps in environmental conditions were confirmed by more elaborate statistical analyses (van Breugel *et al.* 2007). Overlaps in ranges were especially large between forest PNV types, which are all types of the same physiognomic category.

The fact that for some areas of the original map no distinction was made between moist montane and moist intermediate forest clearly shows that the original classification was based on typical species that differentiate between the vegetation types (i.e. a floristic classification), and not on fixed biophysical limits such as altitude or rainfall – although forests were described as moist, dry, montane or intermediate. Trapnell and Brunt (1987) clearly mentioned that it was not possible to distinguish between moist montane and moist intermediate forest in the western area of the original map as heavy cultivation prevented a distinction between the two original vegetation types. Other clear evidence for the floristic classification prior to a climatic interpretation are the genus names used as part of the names of woodland, savanna and some bushland PNV types, such as *Acacia*, *Combretum*, *Commiphora* and *Terminalia*, and the names of forest vegetation classes (Appendix I and II). In his description of forest types for Kenya, Beentje (1990) uses vegetation classes that were mapped by Trapnell (calling the original maps 'a set of excellent maps for upland Kenya' on which he had relied heavily for the distribution of forest vegetation types), whereby he mentions that the names of the forest types often refer to typical species, which are not necessarily the dominant species. Supplementary evidence that boundaries between vegetation types are based on observed differences in vegetation and not on biophysical limits are the several appearances of approximate boundaries (indicated by dashed lines) on the eco-climatic maps between forest types or between the dry montane forest and evergreen and semi-evergreen bushland. Yet another indication that environmental differences were only inferred after vegetation types were floristically differentiated and mapped is the analysis by Trapnell and Griffiths (1960) of how the boundaries of the vegetation types of the Rift valley (dry montane forest, evergreen bushland and upland *Acacia*) could be explained by their lower ratios of rainfall over altitude (< 6 inches of rainfall per 1000 feet altitude; this ratio is confirmed by our data and the pattern can also be observed in Figure 1 as the ratio can also be expressed as a ratio of 1000 mm per 2000 m).

A possible shortcoming in the approach of overlaying the new map with interpolated surface layers is that where values were different (e.g., lower rainfall or higher temperatures), we do not know whether the difference was simply caused by the replacement of the PNV by secondary vegetation, or because of a weaker link between PNV and the spatial data that we used. A possible way to deal with this problem would be to limit the analysis to areas where it is known that the PNV occurs, but we did not have access to such information. However, although climate and edaphic patterns may have changed, altitude will have remained more or less the same as will the derived topographic variables, and conclusions for overlaps in topographic variables will therefore remain the same whether the PNV or a secondary vegetation type generated the environmental layers (although it is also true that elevation changes; the highest peak of Mount Kenya is for example believed to have been over 6000 m whereas the highest peak is now 5199 m [Ojany 2004]).

Environmental layers may also have suffered in accuracy from the interpolation process that was used to obtain a complete surface layer, so that actual trends in between observation points may be different than statistically interpolated. The only method to find out whether patterns as shown by the vegetation boundaries on the map are more correct than those of the interpolated surface layers would be to investigate whether patterns in the environmental layer are significantly different at opposite sites of a vegetation boundary in areas where interpolated surface layers show a more gradual trend, preferably by direct observations of climatic variables. Similarly, obtaining point-specific soil characteristics rather than inferring the characteristics of the dominant soil type may also increase the correspondence between soil characteristics and the distribution of PNV, especially for the three PNV types that occur under soils with impeded drainage (van Breugel *et al.* 2007).

The incomplete correspondence of climatic and vegetation patterns left some room for a possible misclassification of the *Diospyros-Olea* forest type as a dry intermediate forest. An investigation of climatic variables for this forest type showed that the conditions were intermediate between dry intermediate and moist intermediate forests, with in fact mean annual precipitation closer to that of moist intermediate forest, although such analysis was also affected by the resolution of the climate layers (van Breugel, 2007, unpublished data).

White (1983, p. 164) mentions that the distinction between wet and dry forest types is difficult to apply due to the wide tolerance of many species. He does, however, differentiate between afro-montane rain forest and undifferentiated afro-montane forest where he mentions that the latter replaces rain forest on drier slopes at the same altitude and on the wetter slopes at higher altitudes. Elsewhere he stated that afro-montane rain forest species have relatively restricted ranges of humidity and temperature and are confined to the wetter parts of the mountains (White 1978). He also described an apparent paradox of African vegetation that most species of the afro-montane rain forest are restricted to mountains but have congeneric species that occur in lowland areas, whereas most species of the undifferentiated afro-montane forest descend in the surrounding plateaus and have no close relatives in lowland tropics (White 1978). The map of the PNV types shows that dry montane forest occurs above moist montane forest on the wetter slopes of Mount Kenya and Mount Elgon. The fact that rainfall is lower at higher altitudes shows that the distinction between moist and dry forests remains valid (although the climate layers lack much of the required resolution to make the distinction), and we therefore interpreted undifferentiated Afro-montane forest as dry montane forest (Table 5).

The afro-montane rain forest described by White (1983) (with elevation boundaries of 1200 – 2500 m) expands into moist intermediate forest in the eastern part of the map (see also Figure 3). Since moist intermediate forest obtained a separate description for the western part of the map only (as transitional rain forest), we interpreted the afro-montane rain forest as primarily a description of moist montane forest. Some of the species that are listed for moist montane forest in an accompanying document may therefore be expected to occur only or also in moist intermediate forest (Kindt *et al.* 2007).

Two PNV types, upland *Acacia* woodland, savanna and bushland, and lowland *Acacia* woodland, bushland and thicket, contained various physiognomic categories. Two criteria that differentiate between these two types include a separation between highland and lowland areas (we confirmed a boundary in altitude around 1300 m between the two types) and the co-dominance of *Commiphora* for the lowland *Acacia* types. The physiognomic structure offers an additional key to differentiate between the two types, as savanna is only listed for the upland *Acacia*, whereas White (1983) makes a reservation against the use of woodland for lowland *Acacia*, since the trees are only slightly larger than bushland (10 m) and such woodland only occurs in localised positions (White 1983, Table 5). The preliminary classification of Trapnell (Trapnell and Griffiths 1960) reserved the woodlands and savannas for upland *Acacia* types, and bushland and thicket for lowland *Acacia* types. Based on all these references, we interpret the upland *Acacia* vegetation as mainly woodland and savanna, whereas the lowland *Acacia-Commiphora* is mainly bushland and thickets. However, the description of the climate type provided by Trapnell and Brunt (1987, Table 1) only mentions bushland for the upland *Acacia*, whereas the original map listed a larger range of physiognomic types that may still be the best physiognomic description of both PNV types.

Moist *Combretum* savanna is probably secondary vegetation and not a PNV type. For this reason, the vegetation in the area was mapped by White (1983) as a mosaic of Guineo-Congolian rainforest and secondary grassland. Trapnell and Brunt (1987) also mention that information that became available after the maps were published (we expect that this may have been the classification by White [1983]) suggested that moist *Combretum-Terminalia* savanna was secondary to forest (east of Bungoma) or to semi-evergreen thicket (west of Bungoma). Our data confirm the similarity in altitude and rainfall between moist *Combretum* (1280 – 1853 m, 1084 – 1521 mm) and moist intermediate forest (1246 – 1952 m, 1102 – 1639 mm), whereas the difference in rainfall compared to the other savanna types was also clear (Table 6, Figure 5). The rainfall range observed for the savanna types (Figure 5) are generally above the 516 - 784 mm boundary above which African savannas can only be maintained by current disturbance patterns by humans, browsers or fire as they would otherwise become woodlands (Sankaran *et al.* 2005). This finding does not conflict with the definition of PNV as the definition includes all present conditions, but means that explanations of the distribution of the savanna PNV should also include information on disturbance patterns.

A PNV type with no eco-climatic equivalent other than the three PNV on soils with impeded drainage, is broad-leaved savanna-evergreen bushland mixtures (Table 2). The name suggests that this vegetation forms a fine-scaled mosaic of *Combretum* savanna and evergreen and semi-evergreen bushland. Another interpretation could be that such zones are ecotones (see below), which is further suggested by the mention of a mid-*Combretum* savanna type (in between moist and dry savanna) that includes evergreen bushland transition types (Trapnell and Griffiths 1960). This PNV type occupies a small area in the map (only alpine is smaller) and is almost always adjacent to evergreen bushland. Our analysis confirmed that environmental conditions of the mixtures are in between those of the two component PNV types.

4.2 The use of vegetation maps

The classical methodology of phytosociologists is to classify plant communities by moving through a landscape, observing that certain kinds of plant communities repeat themselves under similar environmental conditions and then grouping these plant communities into vegetation types (Whittaker 1978). The fundamental assumption for classification and mapping of different types of plant communities is therefore that they can be identified as discrete units in the landscape. This assumption has long been debated within the history of plant ecology, where the most extreme views are those expressed as the superorganism concept (Clements 1916) and the individualistic concept (Gleason 1917). In the superorganism concept, a community will unidirectionally change to a mono-climax state in a similar way that an organism develops. In the individualistic concept, each species has a unique distribution in space and time and all communities intergrate continuously, so that the chance that a community repeats itself is statistically negligible. The current view is somewhere in the middle of both extremes, as even the proponent of the individualistic distribution himself never doubted the reality of plant communities and the different viewpoints on plant communities can be related to the landscapes in which Clements (a prairie landscape seen from horseback) and Gleason (a forested landscape in which he often walked) grew up in (van der Maarel 2005).

The current view on plant communties is intermediate in agreeing that some communities repeat themselves in time and space, but that a considerable fraction of landscape mosaics consists of ecotones (Kent and Coker 1995; van der Maarel 2005). Within ecotones, species reach their local distribution boundary in species-specific ways so that no sharp boundaries can be observed between plant communities (van der Maarel 2005). A current definition of plant communities (that can be expanded into ecosystems) is that of 'a piece of vegetation in a uniform environment with a relatively uniform floristic composition and structure that is distinct from the surrounding vegetation' (van der Maarel 2005). The inclusion of 'relative' uniform composition and structure in this definition shows that plant communities can be determined, despite the fact that species' distributions do not always coincide completely with those of communities. Austin (2005) mentions that communities are abstractions of geographical space and that the continuum aspect is an abstraction of environmental space. It is possible to make a reasonable prediction of the association of species that would occur on any site, but a certain species may also occur together with another set of species in sites with different conditions (Kent and Coker 1995, Pidwirny 2006).

Several authors have observed that there is a good correspondence between geographic patterns of vegetation and those of climate (e.g., Nahal 1981, Prentice *et al.* 1992, Zeng and Neelin 2000), although climate change may alter such relationships (e.g., Bawa and Markham 1995, Peng 2000, Maslin 2004, Lenihan *et al.* 2003). It is therefore possible to infer climatic conditions from information on vegetation types. Given that networks of climate stations are diminishing and that resolution of spatial datasets is often not of the same detail as historic vegetation maps, it is therefore possible that vegetation maps provide a more informative description of the climatic patterns of a certain area than other sources of information. This is an assumption that can be tested with our maps as it provides detailed boundaries. An illustrative example is that when a detailed vegetation map of Nepal (Shrestha *et al.* 2001) was overlaid by a topographic map (Indian Survey Map, Quarter inches series, Survey of India, 1914-1926), a botanist observed that a vegetation type occurred at an unusual altitude in one area (Lillesø *et al.* 2005). During field checking, it was found out that the vegetation type was correct and the topographic map was wrong in that particular area (T.B. Shrestha, personal communication).

Since vegetation is defined as plant cover, it is clear that there is a link between the distribution of plant species and that of vegetation types (such links are also clear as typical species can be listed for vegetation types in vegetation descriptions or that typical vegetation types are listed for species, but see the discussion above about vegetation classification and ecotones). As a result of the correspondence between climate, vegetation and species, the vegetation map of Africa developed by Frank White turned out to provide boundaries of floristic regions (phytochoria) that showed continental patterns of plant endemism, although no *a priori* information on species distribution had been used to delineate the boundaries (White 1983, p. 41). Since vegetation types, climate and taxonomic composition all correspond to each other, it is also possible to infer prehistoric climatic conditions from information on the historical taxonomic composition of plants (e.g. Jolly *et al.* 1998, Elenga *et al.* 2000). All these findings point in the direction that vegetation maps can also be used to infer the distribution of individual species, which is further discussed in an accompanying document (Kindt *et al.* 2007).

4.3 Limitations of vegetation maps

Although vegetation maps can be used to document the distribution of species, vegetation maps are not necessarily correct for all species (Olson *et al.* 2001). No single biogeographic framework is optimal for all taxa but provides a compromise for as many taxa as possible, and ecoregions contain some habitats that differ from the assigned biome (Whittaker 1978, Olson *et al.* 2001). That vegetation maps do not provide the distribution for all species is also shown by the criterion of 50% of endemism (and not 100%) used as a criterion for African phytochoria (White 1983). It has to be pointed out as well that the correspondence between vegetation and climate is not completely known. Global models therefore do not give predictions of climate that are valid everywhere (Prentice *et al.* 1992).

We want to make it very clear that there may be several limitations to the use of the new PNV maps, although we do not want to imply that we disagree with our earlier statement that PNV maps have much to offer to agroforestry. One of the limitations is that some site conditions may have changed so much that it is not possible to grow a particular species in a place at present, although the species was growing there before. Another limitation is conceptual: the range where a species occurs may only in part overlap with the range where a certain vegetation type occurs, or the same species may occur in a wide range of vegetation types. However, the second situation can be used as a practical advantage because if a species occurs in more than one vegetation type, it indicates that the species probably consists of different populations that are adapted to different environments. In such situations, special care should be taken if the species is to be utilised for planting or is in need of conservation (for an in depth discussion of this common situation, see Graudal *et al.* 1997 and Lillesø *et al.* 2001). The third limitation is closely related to the second one: by classifying vegetation in a number of types, some information on the natural variation in vegetation is lost. Not all boundaries between vegetation types are abrupt and in many situations do ecotones exist between the vegetation types. More details on these three limitations of PNV maps are provided in an accompanying document (Kindt *et al.* 2007). We want to emphasize that these limitations do not mean that the new maps should not be used, but we advise that the maps (i.e. plotted boundaries between vegetation types) should be interpreted cautiously.

5. Conclusion/recommendations

Although the original authors of the vegetation maps provided limited information on the criteria that they used to differentiate between the various vegetation types that they mapped at high resolution (they did not provide any definition of the various types that they mapped), we managed to obtain descriptions of each type from other sources of literature and from geo-spatial datasets. These findings increase our confidence in the accuracy of the original maps and in using these maps to obtain information on climatic and edaphic differences within the study area, although users of the maps should also be aware of limitations of the maps in portraying ecotones or the possibility of fundamental changes in the biotic and abiotic conditions that give rise to a specific potential natural vegetation type (e.g. the influence of global climatic change or the effect of fragmentation on natural regeneration). In an accompanying document (Kindt *et al.* 2007) we provide information on floristic differences between PNV types that can be used as an additional criterion to differentiate between vegetation types and another argument in favour of using the maps as a decision support tool for the selection of indigenous tree species for a particular area.

Since global maps of vegetation and ecoregions continue to be used to study the distribution of biodiversity and to focus conservation efforts, we believe that we can contribute to these processes by (i) providing spatial information that provides more detailed boundaries between vegetation or ecoregional types; (ii) providing species lists that can be added to these vegetation types; and (iii) providing definitions of vegetation types that can be tested by ground truthing. In addition to this, the potential natural vegetation maps can now be used to test the hypothesis that growth and health of indigenous species are influenced by patterns of natural vegetation, which will then give information on genetic differentiation among the different populations of indigenous tree species and how these genetic distribution patterns will affect the long term survival of the species.

6. References

[FAO] Food and Agricultural Organization of the United Nations, 1995b.
FAOCLIM 1.2. A CD-ROM with world-wide agroclimatic data: user's manual. Agrometeorology Series Working Paper No. 11. Rome: FAO.

[FAO] Food and Agricultural Organization of the United Nations, 1998.
The Soil and Terrain Database for northeastern Africa - Crop Production System Zones of the IGAD subregion. FAO Land and Water Digital Media Series 2. FAO, Land and Water Development Division. Rome: FAO.

[FAO] Food and Agricultural Organization of the United Nations, 1995a.
Almanac Characterization Tool (ACT) database SDDR. Rome: FAO.

[GFW] Global Forest Watch, 2006.
Brazilian Amazon: Interactive Map. World Resources Institute's Global Forest Watch Project and the Institute for Man and the Environment in the Amazon (Imazon). URL: http://www.globalforestwatch.org/english/interactive.maps/Brazil.htm.

Austin, M.P., 2005.
Vegetation and environment: discontinuities and continuities. Pp. 52-84 in: van der Maarel E. Vegetation ecology. Oxford: Blackwell Publishing.

Bawa, K.S., Markham, A., 1995.
Climate change and tropical forests. Trends in Ecology and Evolution 10: 348-349.

Beentje, H.J., 1990.
The forests of Kenya. Mitt. Inst. Allg. Bot. Hamburg 23a: 265-286.

Beentje, H.J., 1994.
Kenya Trees, Shrubs and Lianas. National Museums of Kenya, Nairobi, Kenya.

Beven, K.J., Kirkby, N.J., 1979.
A physically based variable contributing area model of basin hydrology. Hydrological Sciences Bulletin 24: 43-69.

Box, E.O. and Fujiwara, 2005.
Vegetation types and their broad-scale distribution. In: van der Maarel E. Vegetation ecology. Oxford: Blackwell Publishing. Pp. 106-128.

Clements, F.E., 1916.
Plant Succession. An analysis of the development of vegetation. Washington: Carnegie Institute.

Corbett, J.D. and Kruska, R.L., 1994.
Africa Monthly Climate Surfaces, v1.0. Based on climate coefficients from CRES, Canberra, Australia. Data for mean long term normal minimum temperature, maximum temperature, and precipitation.. ICRAF/ILRAD, Nairobi, Kenya (CDROM publication),.

Corbett, J.D., Collis, S., Bush, B.R., Muchugu, E.I., O'Brien, R.F., Jeske, R.Q., Burton, R.A., Martinez, R.A., Stone, C.M., White, J.W. and Hodson, D. P., 1999.
East African Country Almanacs. A resource base for characterizing the agricultural, natural, and human environments of Kenya, Ethiopia, Uganda, and Tanzania. CD-ROM.

Elenga ,H., Peyron, O., Bonnefille, R., Jolly, D., Cheddadi, R., Guiot, J., Andrieu, V., Bottema, S., Buchet, G., de Beaulieu, J.L., Hamilton, A.C., Maley, J., Marchant, R., Perez-Obiol, R., Reille, M., Riollet, G., Scott, L., Straka, H., Taylor, D., Van Campo, E., Vincens, A., Laarif, F., Jonson, H., 2000.
Pollen-based biome reconstruction for southern Europe and Africa 18,000 yr BP. Journal of Biogeography 27: 621-634.

Franklin, J., 2002.
Enhancing a regional vegetation map with predictive models of dominant plant species in chaparral. Applied Vegetation Science 5: 135-146.

Froude. V., 1999.
Review of National Databases Relating to Land, Water and Biodiversity. Report prepared for the Ministry for the Environment's Environmental Performance Indicators Programme. New Zealand Ministry for the Environment (URL: http://www.mfe.govt.nz/publications/ser/).

Graudal, L., Kjaer, E.D., Thomsen, A. and Larsen, A.B. 1997.
Planning national programmes for conservation of forest genetic resources. Technical Note No. 48 - December 1997. Danida Forest Seed Centre.

Giesler, R., Högberg, M., Högberg, P., 1998.
Soil chemistry and plants in Fennoscandian boreal forest as exemplified by a local gradient. Ecology 79: 119-137.

Gleason, H.A., 1917.
The structure and development of the plant association. Bulletin of the Torrey Botanical Club 43: 463-481.

Greenway, P.J. 1973.
A classification of the vegetation of East Africa. Kirkia 9, 1-68.

Holmgren, P., 1994.
Topographic and geochemical influence on the forest site quality, with respect to Pinus sylvestris and Picea abies in Sweden. Scandinavian Journal of Forest Research 9: 75-82.

Jolly, D., Prentice, C., Bonnefille, R., Ballouche, A., Bengo, M., Brenac, P., Buchet, G., Burney, D., Cazet, J.P., Cheddadi, R., Edorh, T., Elenga, H., Elmoutaki, S., Guiot, J., Laarif, F., Lamb, H., Lezine, A.M., Maley, J., Mbenza, M., Peyron, O., Reille, M., Reynaud-Farrera, I., Riollet, G., Ritchie, J.C., Roche, E., Scott, L., Semmanda, I., Straka, H., Umer, M., Van Campo, E., Vilimumbalo, S., Vincens, A., Waller, M., 1998.
Biome reconstruction from pollen and plant macrofossil data for Africa and the Arabian peninsula at 0 and 6000 years. Journal of Biogeography 25: 1007-1027.

Kent, M., Coker, P., 1995.
Vegetation description and analysis. A practical approach. Chichester: John Wiley & Sons.

Kindt, R., Lillesø, J.p.b., Van Breugel, P. and Nyabenge, M., 2006.
Potential natural vegetation of south-western Kenya for selection of indigenous tree species. Sheets 1-4. World Agroforestry Centre (ICRAF), Nairobi.

Kindt, R., van Breugel P., Lillesø J. P. B., 2007.
Use of vegetation maps to infer on the ecological suitability of species using central and western Kenya as an example. Part II. Tree species lists for

potential natural vegetation types for central and western Kenya. Development and Environment Series 7-2007. *Forest & Landscape Denmark* and World Agroforestry Centre.

Lenihan, J.M., Drapek, R., Bachelet, D., Neilson, R.P. 2003.
Climate change effects on vegetation distribution, carbon, and fire in Calafornia. Ecological applications 13: 1667-1681.

Lillesø, J.P.B., Dhakal, L.P., Shrestha, T.B., Nayaju, R.P., Shrestha, R. and Kjaer, E.D. 2001.
Tree Planting Zones in Nepal - an ecological approach based on vegetation types. DFSC Case Study No.1. TISC Technical Paper No. 103. Danida Forest Centre, Humlebæk. Tree Improvement and Silviculture Component, Kathmandu.

Lillesø, J-P.B., Shrestha, T.B., Dhakal, L.P., Nayaju, R.P. and Shrestha, R., 2005.
The Map of Potential Vegetation of Nepal - a forestry/agroecological/biodiversity classification system. Forest & Landscape Development and Environment Series 2-2005 and CFC-TIS Document Series No.110
Lind E.M and Morrison, M.E.S. 1974. East African vegetation. London: Longman Group limited.

Maslin, M., 2004.
Ecological versus climatic thresholds. Science 306: 2197-2198.

McGrath, Deborah A., Smith, C.K., Gholz, H.L., de Assis Oliveira, F., 2001.
Effects of land-use change on soil nutrient dynamics in Amazonia. Ecosystems 4: 625-645.

Moore, I.D., Norton, T.W., Williams, J.E., 1993.
Modelling environmental heterogeneity in forested landscapes. Journal of Hydrology 150: 717–747.

Mueller-Dombois, D., Ellenberg, H., 1974.
Aims and methods of vegetation ecology. Caldwell: The Blackburn Press.

Nahal, I., 1981.
The Mediterranean climate from a biological viewpoint. In: di Castro F, Goodall DW, Specht RL, eds. Mediterranean-type shrublands. Amsterdam: Elsevier Scientific Publishing Company. p. 63-85.

Ojany, F.F., 2004.
Kenya: Mount Kenya Biosphere Reserve. In: UNESCO-MAB. Proceedings of the International Launching Workshop. Paris: UNESCO. p. 32-49.

Olson, D.M., Dinerstein, E., Wikramanayake, E.D., Burgess, N.D., Powell, G.V.N., Underwood, E.C., D'amico, J.A., Itoua, I., Strand, H.E., Morrison, J.C., Loucks, C.J., Allnutt, T.F., Ricketts, T.H., Kura, Y., Lamoreux, J.F., Wettengel, W.W., Hedao, P., Kassem, K.R., 2001.
Terrestrial Ecoregions of the World: A New Map of Life on Earth. BioScience 51: 933-938

Pearce, J., Ferrier S., 2001.
The practical value of modelling relative abundance of species for regional conservation planning: a case study. Biological Conservation 98: 33-43.

Pearce, J.L., Cherry, K., Drielsma, M., Ferrier, S. and Whish, G.
Incorporating expert opinion and fine-scale vegetation mapping into statistical models of faunal distribution. Journal of Applied Ecology 38: 412-424.

Peng, C., 2000.
From static biogeographical model to dynamic global vegetation model: a

global perspective on modelling vegetation dynamics. Ecological Modelling 135: 33-54.

Peterson, A.T., Ball, L.G., Cohoon, K.P. 2001.

Predicting distributions of Mexican birds using ecological niche modelling methods. Ibis 144: 27-32.

Pidwirny, M., 2006.

The Physical Environment: An Introduction to Physical Geography. URL: http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/title_page.html (visited 26-07-06).

Prentice, I.C., Cramer, W., Harrison, S.P., Leemans, R., Monserud, R.A., Solomon, A.M. 1992.

A global biome model based on plant physiology and dominance, soil properties and climate. Journal of biogeography 19: 117-134.

R DEVELOPMENT CORE TEAM, 2005

R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. URL http://www.R-project.org.

Sankaran, M., Hanan, N. P., Scholes, R. J., Ratnam, J., Augustine, D. J., Cade, B. S., Gignoux, J., Higgins, S. I., Le Roux, X., Ludwig, F., Ardo, J. Banyikwa, F., Bronn, A., Bucini, G., Caylor, K. K., Coughenour, M. B., Diouf, A., Ekaya, W., Feral, C. J., February, E. C., Frost, P G. H.., Hiernaux, P., Hrabar, H., Metzger, K. L., Prins, H. H. T., Ringrose, S., Sea, W., Tews, J., Worden, J. and Zambatis, N., 2005.

Determinants of woody cover in African savannas. Pp. 846-849. Nature Vol 438|8 December 2005|doi:10.1038/nature04070

Schmidt, F., Persson, A.. 2003.

Comparison of DEM Data Capture and Topographic Wetness Indices. Precision Agriculture 4: 179 - 192.

Schmidt, F., 2002.

Topocrop version 1.2. Topocrop Terrain Indices. ESRI Support Center. http://arcscripts.esri.com/details.asp?dbid=12527. (Accessed February 20, 1997).

Shrestha, T.B., Lillesø, J.P.B., Dhakal, L.P. and Shrestha, R., 2002.

Forest and Vegetation Types of Nepal. Ministry of Forests and Soil Conservation, HMG/Nepal, Natural Resource Management Sector Assistance Programme (NARMSAP), Tree Improvement and Silviculture Component, Kathmandu, Nepal.

Sørensen, R., Zinko, U., Seibert, J., 2006.

On the calculation of the topographic wetness index: evaluation of different methods based on field observations. Hydrology and Earth System Sciences 10: 101-112.

Trapnell, C.G., 1997.

Biodiversity and conservation of the indigenous forests of the Kenya highlands. Bristol: Sansom and company.

Trapnell, C.G., Brunt, M.A., 1987.

Vegetation and climate maps of south-western Kenya. Tolworth Tower: Land Resources Centre.

Trapnell, C.G., Griffiths, J.F., 1960.

The rainfall-altitude relation and its ecological significance in Kenya. East

African Agricultural Journal 25: 207-213.
Trapnell, C.G., Langdale-Brown, I., 1972.
Natural vegetation. In: Morgan WTW, ed. East Africa: its people and resources. Nairobi: Oxford University Press. p. 127-139

Trapnell, C.G., Birch, W.R., Brunt, M.A., 1966.
Kenya 1:250,000 Vegetation Sheet 1. Results of a vegetation – land use survey of south-western Kenya. British Government's Ministry of Overseas Development (Directorate of Overseas Surveys) under the Special Commonwealth African Assistance Plan

Trapnell, C.G., Birch, W.R., Brunt, M.A., Lawton, R.M., 1976.
Kenya 1:250,000 Vegetation Sheet 2. Results of a vegetation – land use survey of south-western Kenya. British Government's Ministry of Overseas Development (Directorate of Overseas Surveys) under the Special Commonwealth African Assistance Plan

Trapnell, C.G., Brunt, M.A., Birch, W.R., 1986.
Kenya 1:250,000 Vegetation Sheet 4. Results of a vegetation – land use survey of south-western Kenya. British Government's Overseas Surveys Directorate, Ordnance Survey under the UK Government's Technical Cooperation Programme

Trapnell, C.G., Brunt, M.A., Birch, W.R., Trump, E.C., 1969.
Kenya 1:250,000 Vegetation Sheet 3. Results of a vegetation – land use survey of south-western Kenya. British Government's Ministry of Overseas Development (Directorate of Overseas Surveys) under the Special Commonwealth African Assistance Plan.

Tüxen, R., 1956.
Die heutige potentielle natürliche Vegetation als Gegenstand der Vegetationskartierung. Angew. Pflanzensoziol. 13: 5-42.

Urban, D.L., Miller, C., Halpin, P.N., Stephenson, N.L., 2000.
Forest gradient responses in Sierran landscapes: the physical template. Landscape Ecology 15: 603-620.

van Breugel, P., Kindt, R. and Lillesø, J.P.B. 2007.
Use of vegetation maps to infer on the ecological suitability of species using central and western Kenya as an example. Part III: Background Study A comparison of the distribution of potential natural vegetation and environmental conditions in south western Kenya. Development and Environment Series 2007. *Forest and Landscape Denmark* and World Agroforestry Centre, Kenya. in prep.
van der Maarel, E., 2005.
Vegetation ecology – an overview. In: van der Maarel E. Vegetation ecology. Oxford: Blackwell Publishing. p. 106-128.

Wells, M.L., O'Leary, J., Franklin, J., Michaelsen, J., Kinsey, D., 2004.
Variations in a regional fire regime related to vegetation type in San Diego County, California (USA). Landscape Ecology 19: 139-152.

Western, A.W., Grayson, R.B., Blöschl, G., Willgoose, G.R., McMahon, T.A., 1999.
Observed spatial organization of soil moisture and its relation to terrain indices. Water Resources Research 35: 797–810.

Whittaker, R.H., 1978.
Approaches to classifying vegetation. Pages 3-31 in Whittaker, R.H. 1978. Classification of plant communities. Dr. W. Junk Publishers, Boston, USA.

White, F., 1978.
The Afro-montane region. In: Werger MAJ, ed. Biogeography and Ecology of Southern Africa. The Hague: Junk. P. 465-513.

White, F., 1983.
The vegetation of Africa: a descriptive memoir to accompany the UNESCO / AETFAT / UNSO vegetation map of Africa by F White. Natural Resources Research Report XX, Paris: UNESCO.

White, J.D., Running, S.W., 1994.
Testing scale-dependent assumptions in regional ecosystem simulations. Journal of Vegetation Science 5: 687–702.

Zeng, N., Neelin, J.D., 2000.
The Role of Vegetation–Climate Interaction and Interannual Variability in Shaping the African Savanna. Journal of Climate 13: 2665-2670.

Zinko, U., Seibert, J., Dynesius, M., Nilsson, C., 2005.
Plant species numbers predicted by a topography based groundwater-flow index. Ecosystems 8: 430-441.

7. Appendices

Appendix I. Correspondence between potential natural vegetation types and original vegetation types (groups, subgroups and classes)

Potential natural vegetation	Code	Original group or subgroup	Original class
Bamboo woodland and thicket	41	High mountain woodland	Clearings and scrub from bamboo vegetation
	48	High mountain woodland	High mountain woodland (*Hagenia-Hypericum* woodland and scrub)
	51	High mountain woodland	Bamboo woodland and scrubland
	59	High mountain woodland	Mountain bamboo thicket
Mountain scrubland and moorland	7	High mountain vegetation	Undifferentiated moorland
	15	High mountain scrub types	High mountain scrub types, undifferentiated
Alpine vegetation	7	High mountain vegetation	Alpine (Giant groundsel and Lobelia) vegetation
Moist montane forest	2 (pp)	Open grassland types on drained soils	Other grasslands and scrub grasslands of forest origin, undifferentiated
	3 (pp)	Montane open grasslands and forest glades	Undifferentiated forest glades
	4 (pp)	Broad-leaved savanna types of probable forest origin	Cultivated *Erythrina* and *Erythrina-Vernonia* types (savanna-like vegetation), undifferentiated
	5 (pp)	Montane *Acacia* vegetation of probable forest origin	Undifferentiated secondary and valley types
	26	Clearings and cultivation communities from upper moist montane forest	Undifferentiated clearings and cultivations
	27	Montane evergreen and sclerophyll forest types	Moist montane forest, undifferentiated
	35 (pp)	Clearings and cultivation communities from moist montane and intermediate forests	Undifferentiated clearings and scrub / *Catha edulis* thicket and scrub mixtures
	49 (pp)	Broad-leaved savanna types of probable forest origin	*Faurea, Protea, Erythrina* and *Combretum* hill types, undifferentiated
Dry montane forest	2 (pp)	Open grassland types on drained soils	Other grasslands and scrub grasslands of forest origin, undifferentiated
	3 (pp)	Montane open grasslands and forest glades	Undifferentiated forest glades
	4 (pp)	Broad-leaved savanna types of probable forest origin	Cultivated *Erythrina* and *Erythrina-Vernonia* types (savanna-like vegetation), undifferentiated
	5 (pp)	Montane *Acacia* vegetation of probable forest origin	Undifferentiated secondary and valley types
	10	Upland *Acacia* savanna of probable montane sclerophyll (dry *Juniperus* type) forest origin	*Acacia* types
	13	Semi-deciduous bushland of probable montane sclerophyll forest origin	*Dodonaea-Tarchonanthus* mixture
	14	Semi-deciduous bushland of probable montane sclerophyll forest origin	Evergreen woodlands
	16	Clearings and cultivation communities from montane sclerophyll forest	Secondary mountain scrub and scrub grassland

Potential natural vegetation	Code	Original group or subgroup	Original class
Dry montane forest	17	Clearings and cultivation communities from montane sclerophyll forest	*Juniperus* and *Acokanthera* tree-grassland
	31 (!)	Montane *Acacia* vegetation of probable forest origin	Montane *Acacia* with *Tarchonanthus*
	39	Montane evergreen and sclerophyll forest types	Dry *Juniperus* type
	42	Montane evergreen and sclerophyll forest types	Montane sclerophyll forest, undifferentiated
	49 (pp)	Broad-leaved savanna types of probable forest origin	*Faurea, Protea, Erythrina* and *Combretum* hill types, undifferentiated
Moist ntermediate forest	2 (pp)	Open grassland types on drained soils	Other grasslands and scrub grasslands of forest origin, undifferentiated
	3 (pp)	Montane open grasslands and forest glades	Undifferentiated forest glades
	4 (pp)	Broad-leaved savanna types of probable forest origin	Cultivated *Erythrina* and *Erythrina-Vernonia* types (savanna-like vegetation), undifferentiated
	5 (pp)	Montane *Acacia* vegetation of probable forest origin	Undifferentiated secondary and valley types
	25	Clearings and cultivation communities from lower moist intermediate forest	Undifferentiated clearings and cultivations / riverine alluvium
	27	Montane evergreen and sclerophyll forest types	Moist Montane forest, undifferentiated
	35 (pp)	Clearings and cultivation communities from moist montane and intermediate forests	Undifferentiated clearings and scrub / *Catha edulis* thicket and scrub mixtures
	36	Intermediate, mainly semi-deciduous forest types	Moist Intermediate forest, undifferentiated
	49 (pp)	Broad-leaved savanna types of probable forest origin	*Faurea, Protea, Erythrina* and *Combretum* hill types, undifferentiated
Dry intermediate forest	2 (pp)	Open grassland types on drained soils	Other grasslands and scrub grasslands of forest origin, undifferentiated
	3 (pp)	Montane open grasslands and forest glades	Undifferentiated forest glades
	4 (pp)	Broad-leaved savanna types of probable forest origin	Cultivated *Erythrina* and *Erythrina-Vernonia* types (savanna-like vegetation), undifferentiated
	5 (pp)	Montane *Acacia* vegetation of probable forest origin	Undifferentiated secondary and valley types
	17	Clearings and cultivation communities from intermediate *Diospyros* (-*Olea*) forest	Undifferentiated clearings and scrub
	18	Intermediate, mainly semi-deciduous forest types	Intermediate *Diospyros-Olea* forest
	23	Semi-deciduous bushland of probable dry intermediate forest forest origin, *Croton* and allied scarp types	*Dodonaea-Tarchonanthus* mixture
	23	Semi-deciduous bushland of probable intermediate *Diospyros* (-*Olea*) forest origin	Dodonaea-Tarchonanthus mixture
	34	Clearings and cultivation communities from dry intermediate forest	Undifferentiated clearings and scrub
	36	Intermediate, mainly semi-deciduous forest types	Moist Intermediate forest, undifferentiated

Potential natural vegetation	Code	Original group or subgroup	Original class
Dry intermediate forest	45	Intermediate, mainly semi-deciduous forest types	Dry intermediate forest, undifferentiated
	49 (pp)	Broad-leaved Savanna types of probable forest origin	*Faurea, Protea, Erythrina* and *Combretum* hill types, undifferentiated
Upland *Acacia* woodland, savanna and bushland	19	Upland *Acacia* woodlands, savanna and bushland	Transitional *Acacia* mixtures, undifferentiated
	29	Upland *Acacia* woodlands, savanna and bushland	Proper upland *Acacia* type, undifferentiated
	30	*Acacia* on recent alluvium	*Acacia xanthophloea* type (and *Acacia kirkii*)
	55	Upland *Acacia*types with Tarchonanthus	*Tarchonanthus-Acacia*
Broad-leaved savanna-evergreen bushland mixtures	52	Broad-leaved savanna-evergreen bushland Mixtures	Mixed savanna and bushland species, undifferentiated
***Acacia-Commiphora* low woodland, thicket and bushland**	6	*Acacia*-desert scrub vegetation	*Acacia*scrubland
	11	Mixed dry *Acacia* vegetation	Mixed *Acacia* bushland
	12	*Acacia*-desert scrub vegetation	*Acacia tortilis*-desert shrub on alluvium
	19	*Acacia-Commiphora* low woodland, thicket and bushland	*Combretum Acacia-Commiphora* transition type
	20	*Acacia-Commiphora* low woodland, thicket and bushland	Commiphora - *Acacia* vegetation, undifferentiated
	21	Mixed dry *Acacia* vegetation	*Acacia* thickets and woodlands
Dry Combretum savanna	43	Dry / Eastern *Combretum* and allied vegetation	Undifferentiated dry *Combretum* types, including cultivated areas
Moist Combretum-Terminalia savanna	40	Moist *Combretum* and allied vegetation	Undifferentiated *Combretum-Terminalia* types, including cultivated areas
Evergreen and semi-decidous bushland	1	Open grasslands from evergreen and semi-deciduous bushland	Undifferentiated secondary grasslands
	10	Upland *Acacia* (types) from evergreen and semi-Deciduous Bushland	*Acacia* derived savanna
	13	Upland evergreen and semi-deciduous bushland types	Open evergreen and semi-deciduous bushland of central Rift region, undifferentiated
	14	Upland evergreen and semi-deciduous bushland types	Open evergreen and *Acacia*-evergreen bushland of Eldoret plateau region, undifferentiated
	22	Upland *Acacia* (types) from evergreen and semi-deciduous Bushland	*Acacia brevispica*
	24	Upland evergreen and semi-deciduous bushland types	Upland dense evergreen (woodland and) bushland, undifferentiated
	58	Upland evergreen and semi-deciduous bushland types	*Tarchonanthus* ridges
	61	Upland *Acacia* (types) from evergreen and semi-deciduous Bushland	Allied *Acacia* drepanolobium vegetation
Semi-evergreen thicket	37	Broad-leaved savanna mixtures of semi-evergreen thicket origin	Denuded hill country with thicket remnants, probably with secondary *Acacia*
	44	Broad-leaved savanna mixtures of semi-evergreen thicket origin	*Heeria - Rhus* and allied Lannea and *Acacia-Lannea* savanna
	46	Intermediate semi-evergreen thicket and deciduous thicket (and associated types)	Derived clearings, cultivation communities and bushland, undifferentiated
	50	Broad-leaved savanna mixtures of semi-evergreen thicket origin	Semi evergreen or deciduous thicket mixtures

Potential natural vegetation	Code	Original group or subgroup	Original class
Semi-evergreen thicket	60	Intermediate semi-evergreen thicket and deciduous thicket (and associated types)	Intermediate semi-evergreen ticket
	62	Intermediate semi-evergreen thicket and deciduous thicket (and associated types)	Intermediate secondary *Acacia* thicket (*Acacia brevispica* escarpment thicket)
	101	Open grassland types on drained soils	Open grasslands of semi-evergreen thicket origin
***Papyrus* and swamp**	9	vegetation of soils with impeded drainage	*Papyrus*, swamp grass and reed swamp
Open grassland areas on clay plains	32	Open grassland areas on clay plains	Saline grassland and salt pans
***Acacia* and allied vegetation on clay plains**	8	Grasslands and clump-grasslands, undifferentiated	Vlei and drainage-line types
	47	*Acacia* and allied vegetation on clay plains	*Themeda* and *Themeda - Pennisetum* (*mezianum*) grasslands
	56	*Acacia* and allied vegetation on clay plains	*Acacia* and allied vegetation on clay plains, undifferentiated

(!): Reclassified into various forest types based on the ecoclimaric map (see methods).

(pp): "pro parte", part of the whole vegetation type.

Appendix II. Correspondence between vegetation classes and subclasses of the original map. The code for the vegetation class corresponds to Appendix I.

Code	Original subclass
1	*Achyranthes - Justicia* dwarf scrub - grasslands
	Grasslands of Eldoret Plateau region
	Open grasslands of semi-evergreen thicket origin
2	From dry *Juniperus* forest
	From moist montane and intermediate forests
	From montane sclerophyll (moist *Juniperus*) forest
4	From dry intermediate forest
	From intermediate *Diospyros-Olea* forest
	From moist intermediate forest
	From montane sclerophyll forest
5	From intermediate *Diospyros* forest
	From moist intermediate forest
	From moist montane forest
	From montane sclerophyll forest
6	*Acacia reficiens* ssp. *misera* bushland
	Acacia semi-desert scrub
8	Clump grassland with *Acacia* gerrardii
	Evergreen clump-grassland on vlei soils
10	*Acacia brevispica*, *A. mellifera*, etc
	Acacia drepanolobium derived savanna
	Acacia gerrardii and *A. seyal* derived savanna
	Acacia hockii derived savanna
11	Mixed *Acacia* bushland of Athi Valley
	Mixed *Acacia* bushland of Baringo basin
	Mixed *Acacia* scarp bushland
13	*Dodonaea* and *Dodonaea-Combretum*
	Dodonaea-Olinia and *Dodonaea-Combretum*
	Dodonaea-Tarchonanthus mixture
	Evergreen bush-clump vegetation
	Open *Marua* grassland with *Psiadia*, etc.
	Open *Rhus-Acacia gerrardii* bushland
	Open *Rhus-Olea* and *Acokanthera* bushland
	Scattered *Euphorbia*, (*Balanites*, etc) in bushland
	Tarchonanthus with *Acacia gerrardii*, *A. seyal*, etc
	Tarchonanthus with broad-leaved savanna species
	Tarchonanthus with dry thicket elements
	Tarchonanthus with evergreen bushes
	Tarchonanthus with upland or montane *Acacia*
	Tarchonanthus with scattered evergreens
	Tarchonanthus-Acacia drepanolobium
	Tarchonanthus-Maerua alluvium
	Uvaria and *Dodonaea-Uvaria*
14	Dense evergreen woodland and bushland
	Open evergreen and semi-deciduous bushland
	Mixed *Rhus* clump-*Acacia gerrardii* type
	Olea-Rhus clumps with *Hyparrhenia*
15	Tree heather, low-level mixtures
	Tree heather, thicket and scrub
16	Clearings and scrub from marginal types
	Clearings and scrub from *Podocarpus* and moist *Juniperus* types
	Cultivated moist *Vernonia* etc.
	Moist *Juniperus* clump-grassland
	Podocarpus and moist *Juniperus* grassland
17	*Acokanthera* and allied tree-grassland
	Burnt-out clump grassland
	Clearings and scrub from dry *Juniperus* type
	Dry *Juniperus* clumps and tree-grassland

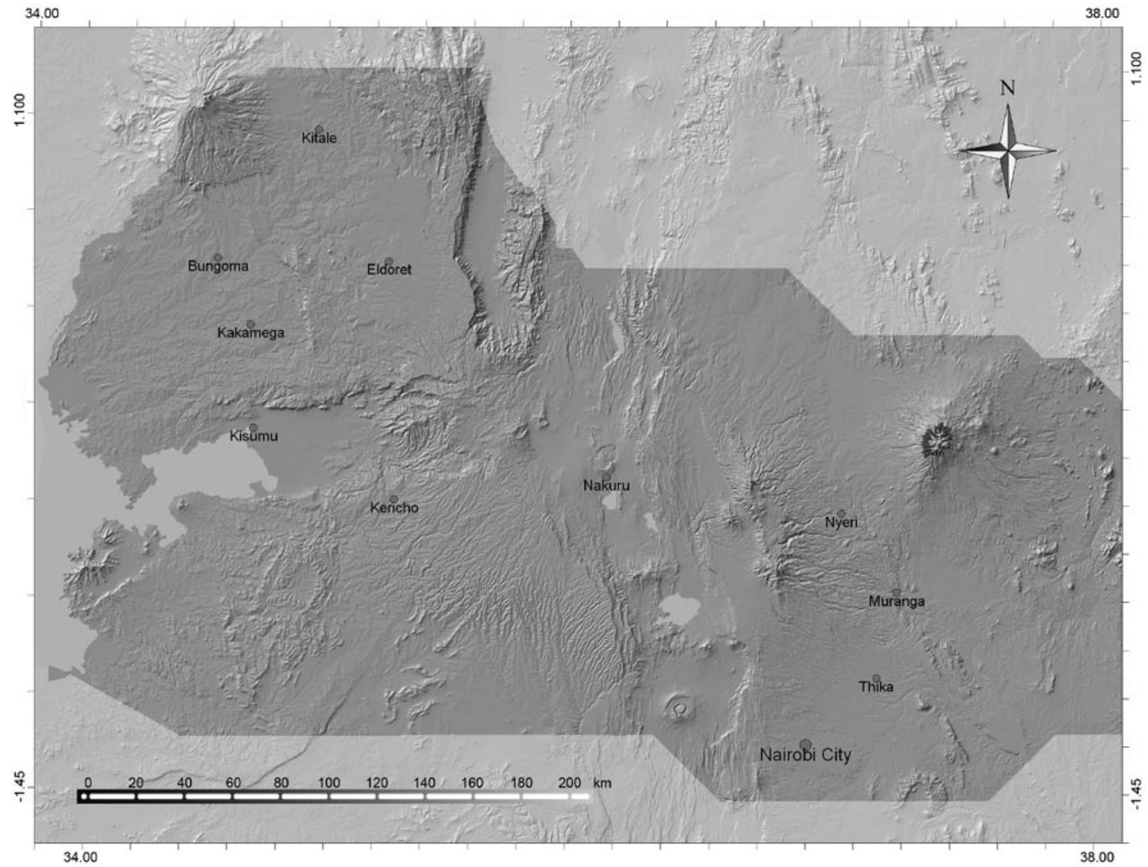
Code	Original subclass
	Dombeya and allied clump vegetation
	Evergreen clump-grassland
19	*Acacia -Combretum* mixtures
	Acacia tortilis-Terminalia etc
	Albizia sericocephala-Acacia type
	Combretum Acacia - Commiphora transition type
20	*Acacia brevipica* transition thicket
	Acacia tortilis etc cultivated areas
	Acacia-Comniphora bushland
	Commiphora thicket and woodland
	Open *Acacia - Commiphora* with *Adansonia*
	Open *Acacia* tortilis
21	*Acacia* thicket with Capparidaceae (alluvium)
	Acacia tortilis woodland (alluvium)
22	*Acacia brevispica - Acacia drepanolobium* with evergreen elements on basement soils
	Acacia brevispica - Acacia drepanolobium with evergreen elements on lava soils
23	*Dodonaea* and *Dodonaea-Combretum*
	Dodonaea-Tarchonanthus mixture
	Tarchononthus
24	Derived evergreen or semi-deciduous thicket
	Evergreen or semi-deciduous lava bushland
	Marginal dry thicket with succulents
25	*Chlorophora* tall grass areas
	Cordia-Acacia-Erythrina with scattered *Chlorophora*
	Cultivated *Albizia-Bridelia-Vernonia*
	Cultivated *Albizia-Bridelia-Vernonia* with scattered *Chlorophora*
	Cultivated *Cordia-Bridelia* types
	Cultivated *Cordia-Markhamia-Croton*
	Cultivated *Croton -Lantana* areas
	Cultivated *Croton-Vernonia-Acanthus*
	Cultivated *Macaranga, Harungana* etc
	Marginal *Cordia* mixtures with savanna trees
	Riverine alluvium from intermediate forest
	Riverine alluvium with *Cholorphora*
26	Cultivated areas with *Conopharyngia*
	Cultivated areas with *Cordia* and *Prunus*
	Cultivated areas with *Cyperus*
	Cultivated areas with *Hagenia*
	Cultivated *Triumfetta, Clerodendron* and bracken
	Myrica-Harungana and other *Myrica* mixtures
27	*Albizia-Polyscias* and *Neoboutonia* types
	Aningeria high forest type
	Forest with *Catha edulis* belts
	Marginal *Macaranga* type
	Ocotea high forest type
	Podocarpus milanjianus type
	Upper marginal type
29	*Acacia brevispica* and *A. tortilis* scarp types
	Acacia drepanolobium - Pennisetum stramineum
	Acacia etbaica - A. brevispica thicket and bushland
	Acacia mellifera - Pennisetum stramineum
	Acacia tortilis belts
	Open *Acacia* tree-grassland types
	Undifferentiated basement complex types
	Upland *Acacia*, Baringo basin type
30	*Acacia gerrardii* type
	Acacia kirkii type
	Acacia polyacantha type
34	Cultivated *Albizia-Croton-Cordia* type
	Cultivated areas with *Croton macrostachyus*
	Cultivated *Croton - Erythrina - Lantana*
	Cultivated with *Euclea* remnants

Code	Original subclass
35	*Catha edulis* thicket and scrub mixtures
	Cultivated *Croton* and *Vernonia-Clerodendron*
	Cultivated Kikuyu grass areas
	Cultivated *Macaranga, Harungana* etc
	Cultivated *Prunus* and *Prunus-Cordia-Albizia*
	Cultivated *Triumfetta - Vernonia*
	Maesa and allied scrub
36	*Croton megalocarpus* type
	Lovoa swynnertonii type
	Marginal *Croton megalocarpus*
	Marginal *Premna* type
	Newtonia buchananii type
40	Burnt-out savanna grassland areas
	Combretum with *Euclea schimperi*
	Combretum with semi-evergreen thicket termitaria
	Cultivated *Ficus, Albizia*, etc
	Cultivated *Vernonia, Bridelia*, etc
	Derived *Acacia* and *Acacia-Combretum*
	Erythrina-Heeria-Combretum type
	Faurea speciosa-Combretum-Erythrina type
	Parinari and *Parinari - Combretum* mixtures
	Piliostigma and *Combretum - Piliostigma* on clay plains
42	*Euphorbia* type with little *Podocarpus*
	Forest regrowth with *Dombeya* etc
	Marginal *Prunus* type or allied type
	Podocarpus gracilior and mixed *Podocarpus* types
	Podocarpus milanjianus type
	Podocarpus-Juniperus and moist *Juniperus* types
	Upper marginal type
43	Burnt out grassland and *Acacia*-grassland areas
	Combretum and *Heeria-Combretum* types
	Combretum with evergreen bush-clumps
	Combretum with sparse *Dodonaea*
	Combretum-Comniphora mixtures
	Combretum-Diospyros type
	Cultivated *Thespesia, Piliostigma* and *Croton* areas
	Derived *Acacia* and *Acacia-Combretum*
	Derived *Lantana* and *Lantana-Combretum*
	Faurea saligna-Combretum type
	Parinari-Combretum and *Faurea* mixtures
	Terminalia and *Combretum-Terminalia* types
45	*Brachylaena hutchinsii* type
	Croton megalocarpus type
	Marginal *Calodendron* type
	Marginal *Croton* scarp type
46	*Acacia brevispica-Rhus-Harrisonia* type
	Albizia coriaria-Turraea type
	Aspilia etc derived scrub (eastern type)
	Balanites and *Acacia seyal - Balanites* types
	Derived *Lantana* scrub
	Escarpment type with Euphorbia
	Euphorbia - Rhus - Acacia seyal mixtures
	Ipomoea cultivated areas
47	*Acacia drepanolobium* dominant
	Acacia mellifera type
	Acacia seyal clay plains
	Balanites-grassland type
	Lannea - Combretum mixture
	Secondary *Acacia polyacantha*
49	*Combretum* hill types of probable montane forest origin
	Combretum mixtures of probable intermediate forest origin
	Protea hill types of probable montane forest origin
50	*Combretum*-semi-evergreen thicket mixture / remnant

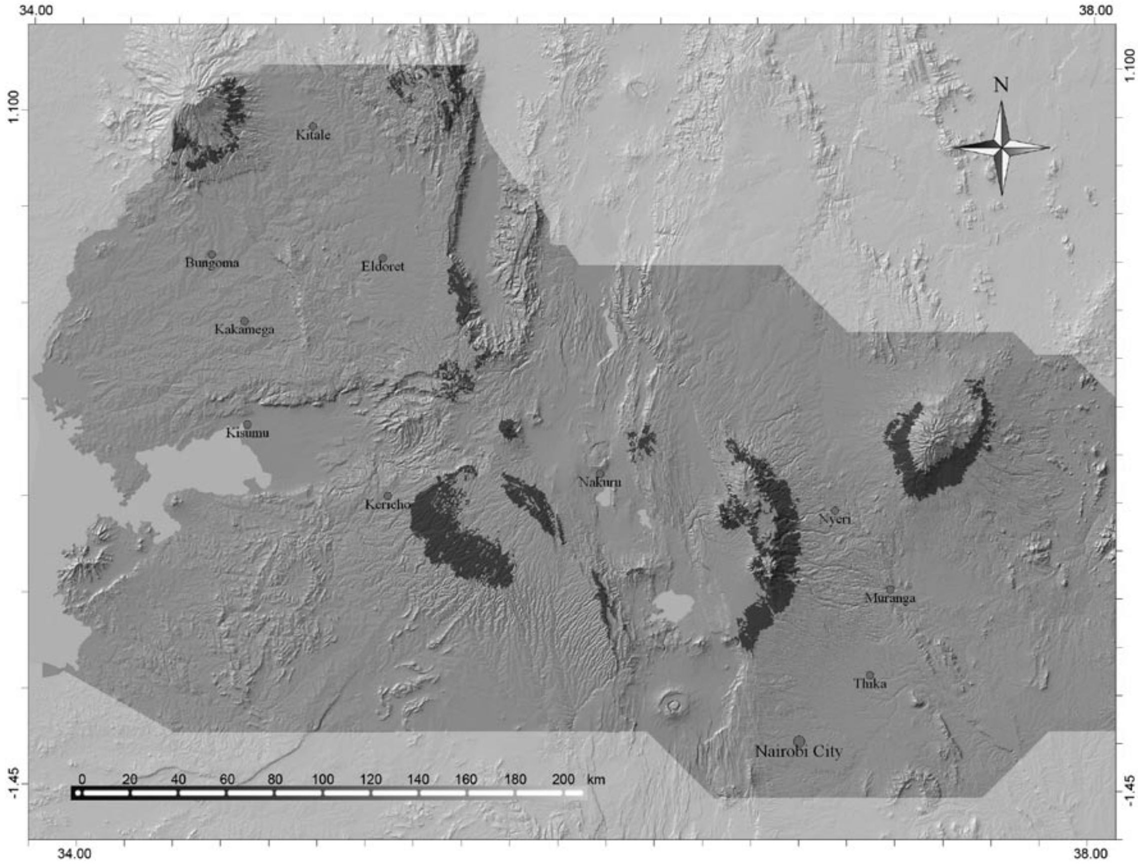
Code	Original subclass
	Cultivated *Terminalia*, *Vitex* and *Parinari*
	Parinari with semi-evergreen thicket remnants / mixture
	Terminalia semi-deciduous thicket mixture
51	Bamboo-forest mixtures
	Bamboo-woodland and scrub mixtures
	Open forest with gaps of bamboo origin
52	Allied scarp mixtures with *Dodonaea* or *Uvaria*
	Combretum-Acacia-evergreen bushland mixture with evergreen bushland elements
	Combretum-evergreen bushland mixture
	Heeria-Dombeya-evergreen bushland mixture
	Lannea-Terminalia-Acacia mixture
	Terminalia-Acacia-evergreen bushland mixture
55	*Tarchonanthus* - *Acacia* mellifera
	Tarchonanthus - upland *Acacia* mixture
56	*Acacia gerrardii* type with impeded drainage
	Acacia seyal and *Acacia-Balanites*
	Acacia sieberiana vars. and *A. polyacantha*
	Euphorbia (with *Acacia*) and thicket remnants
	Hyparrhenia - Pennisetum catabasis
58	*Tarchonanthus-Albizia* ridges
	Tarchonanthus-*Combretum* ridges
60	Intermediate succulent and (semi-)deciduous thicket
	Intermediate thicket, eastern type
61	*Acacia drepanolobium* with evergreen elements on pedocal and impeded drainage soils
	Allied *Acacia* - grassland mixture
	Allied *Acacia drepanolobium* savanna

Appendix III. Small-scale distribution maps for the 17 potential natural vegetation maps

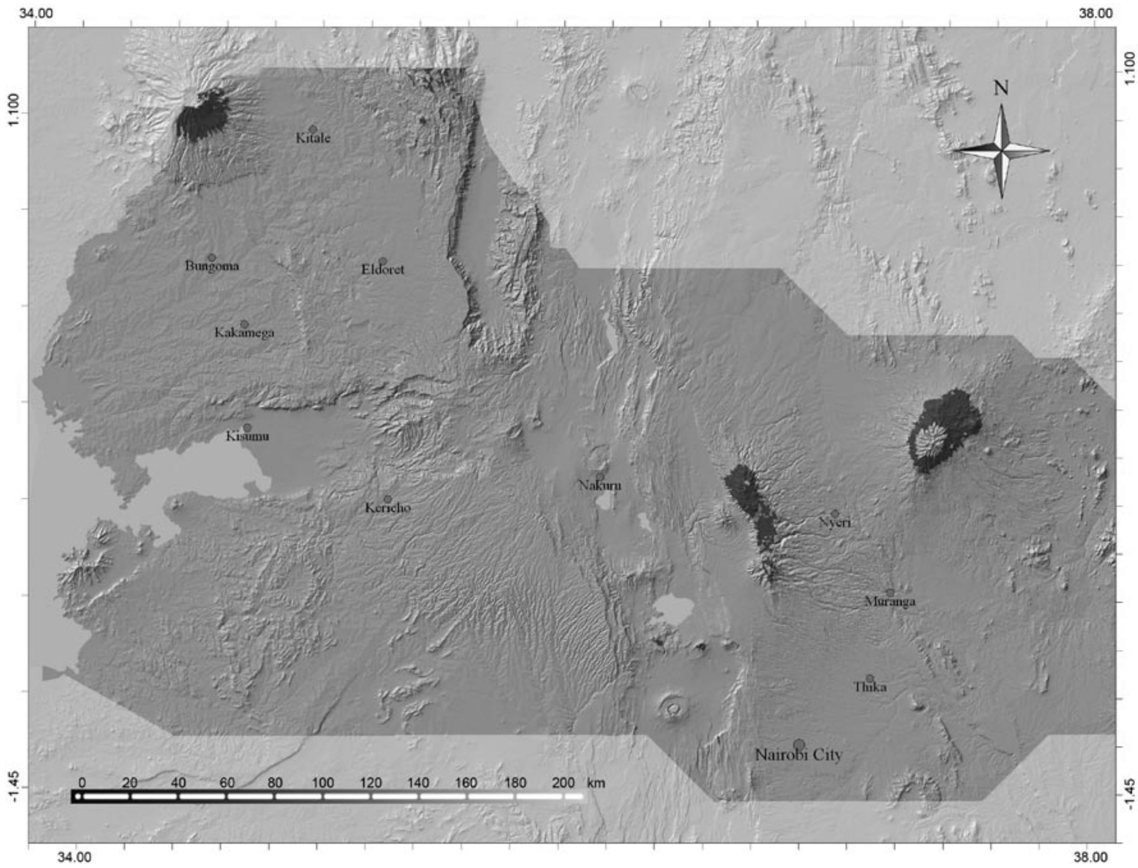
Alpine
Bamboo woodland and thicket
Mountain scrubland and moorland
Moist montane forest
Dry montane forest
Moist intermediate forest
Dry intermediate forest
Upland Acacia woodland, savanna and bushland
Broad-leaved savanna-evergreen bushland mixtures
Lowland Acacia-Commiphora woodland, bushland and thicket
Moist Combretum-Terminalia savanna
Dry Combretum savanna
Evergreen and semi-evergreen bushland
Semi-evergreen thicket
Papyrus and swamp
Open grassland areas on clay plains
Acacia and allied vegetation on soils with impeded drainage



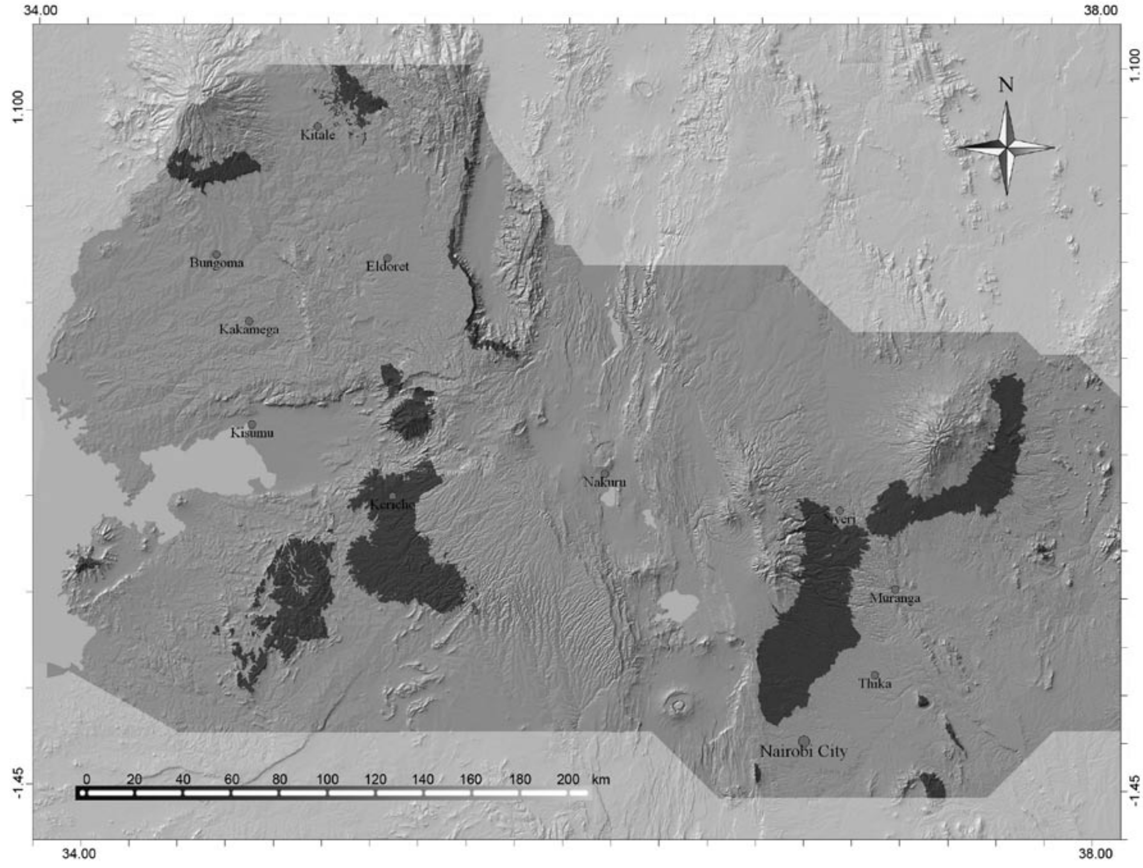
Alpine



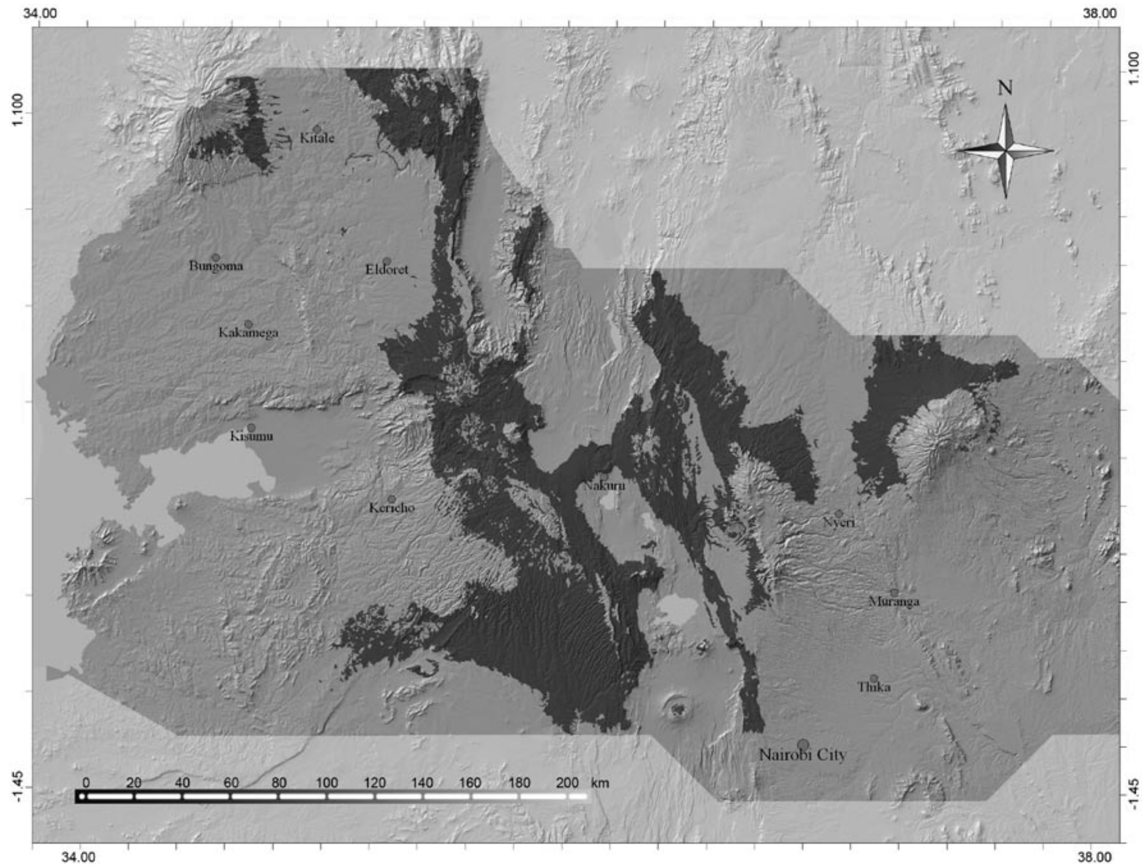
Bamboo woodland and thicket



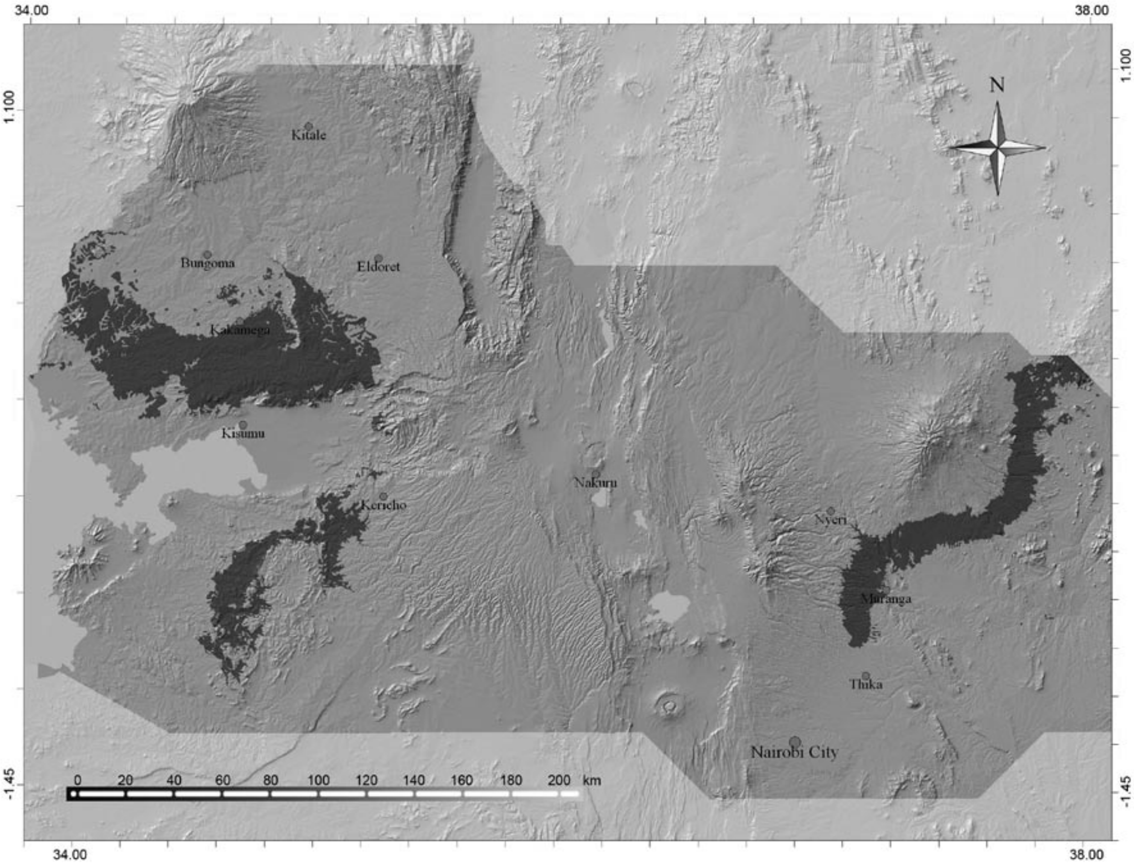
Mountain scrubland and moorland



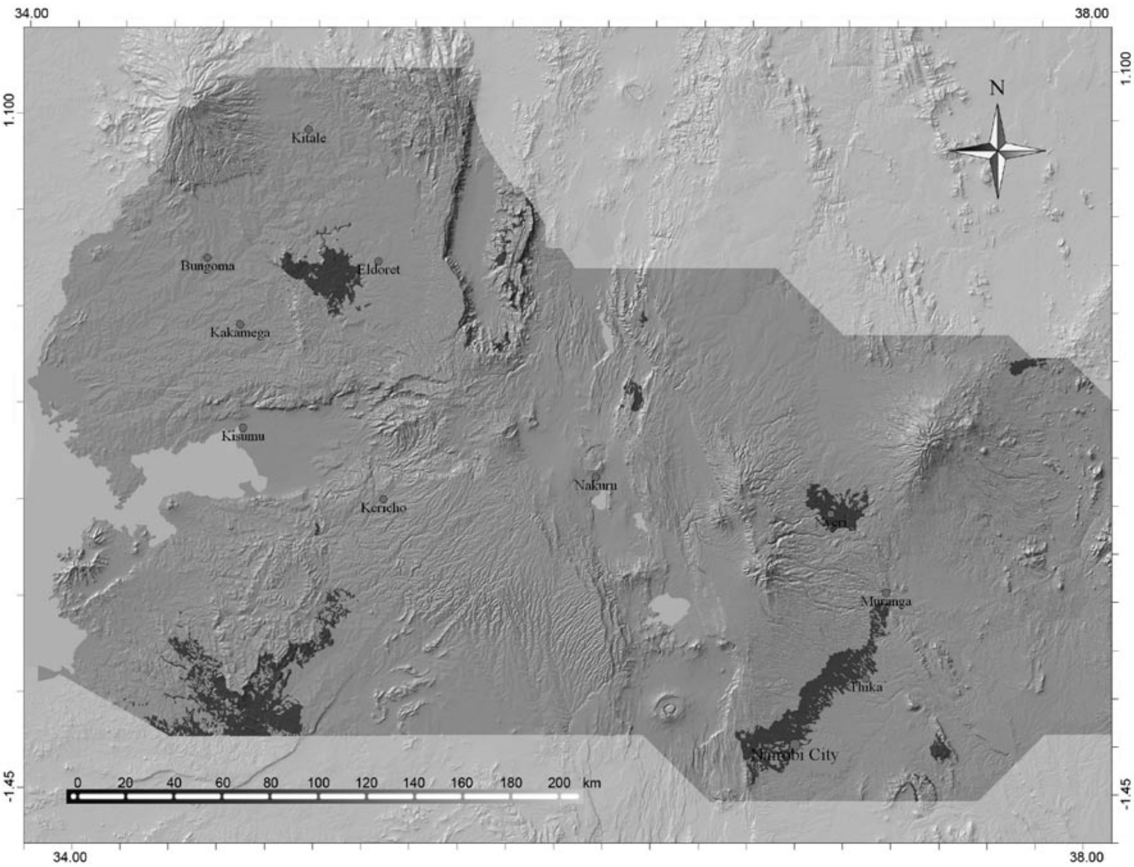
Moist montane forest



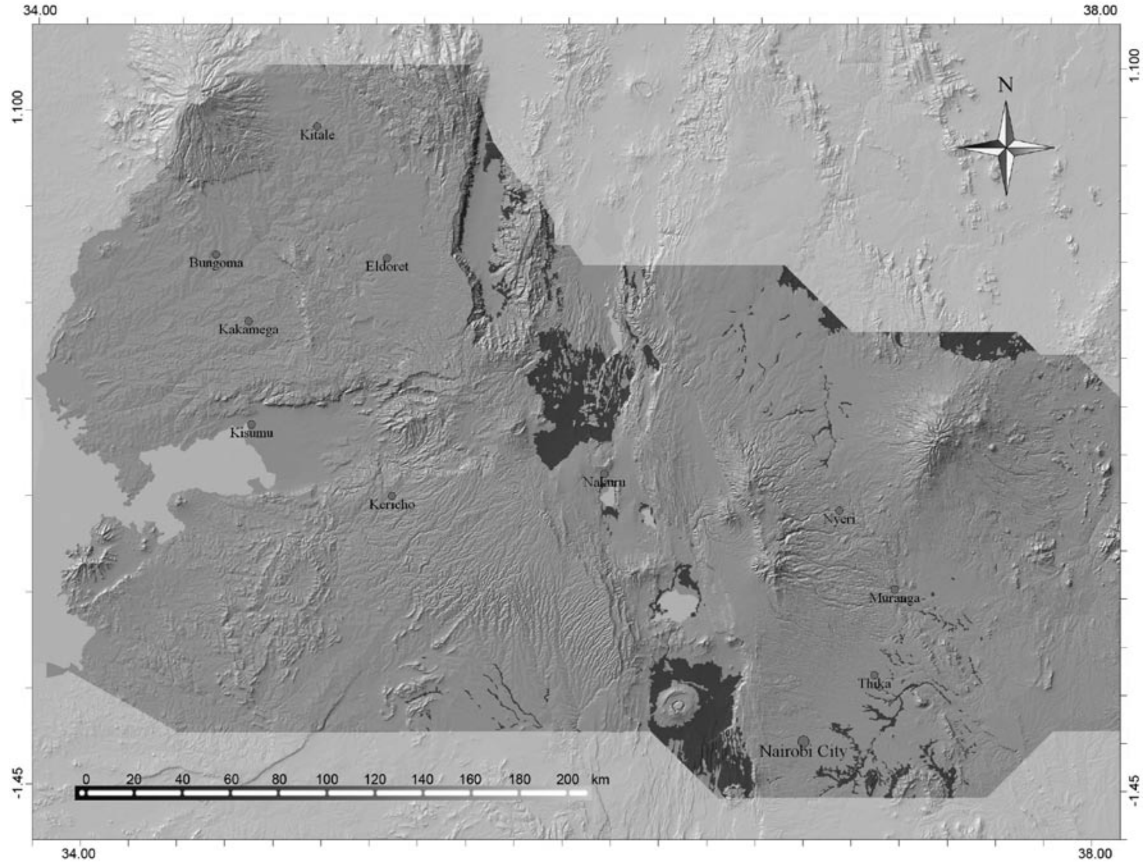
Dry montane forest



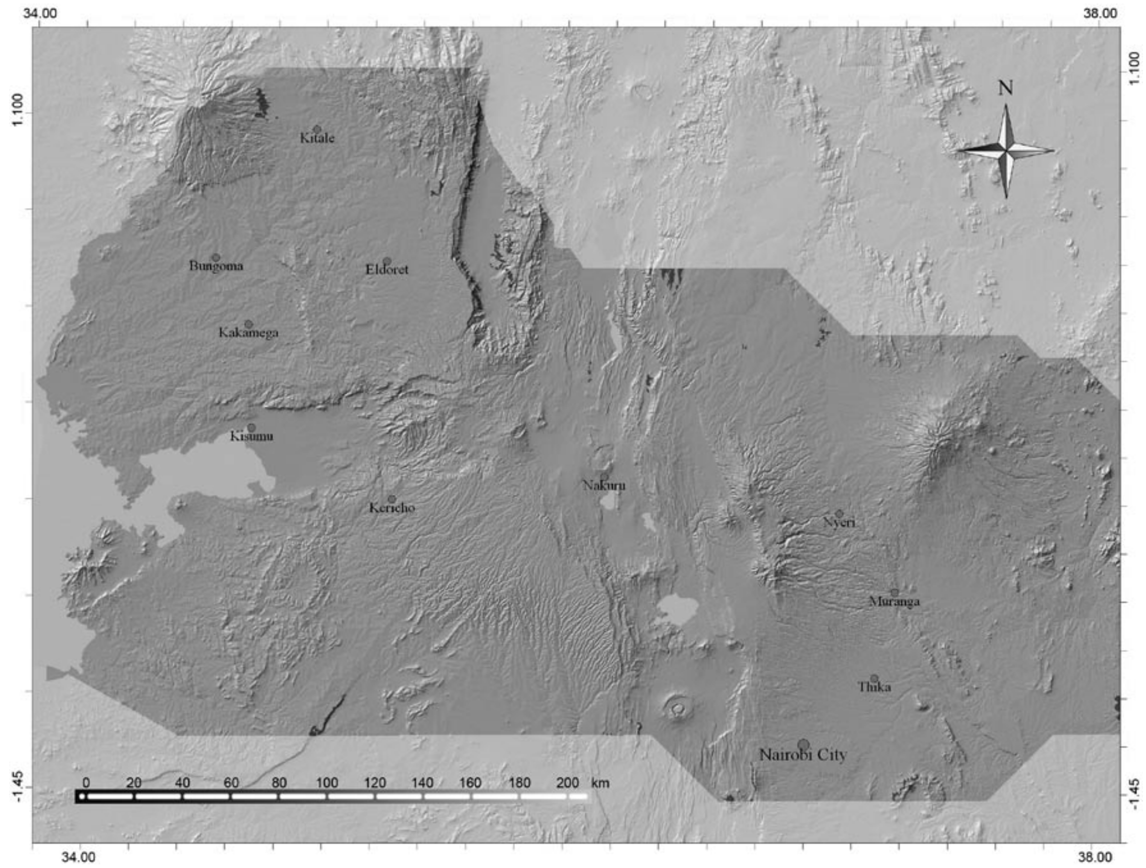
Moist intermediate forest



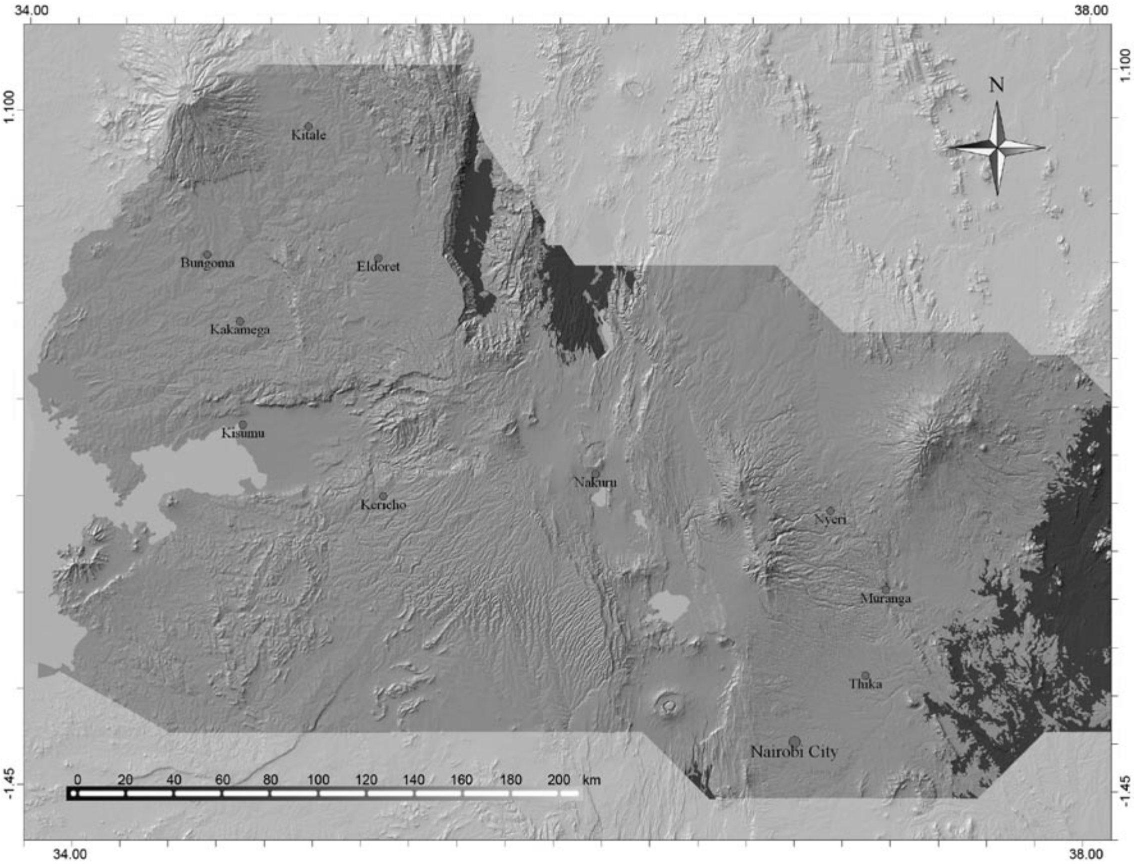
Dry intermediate forest



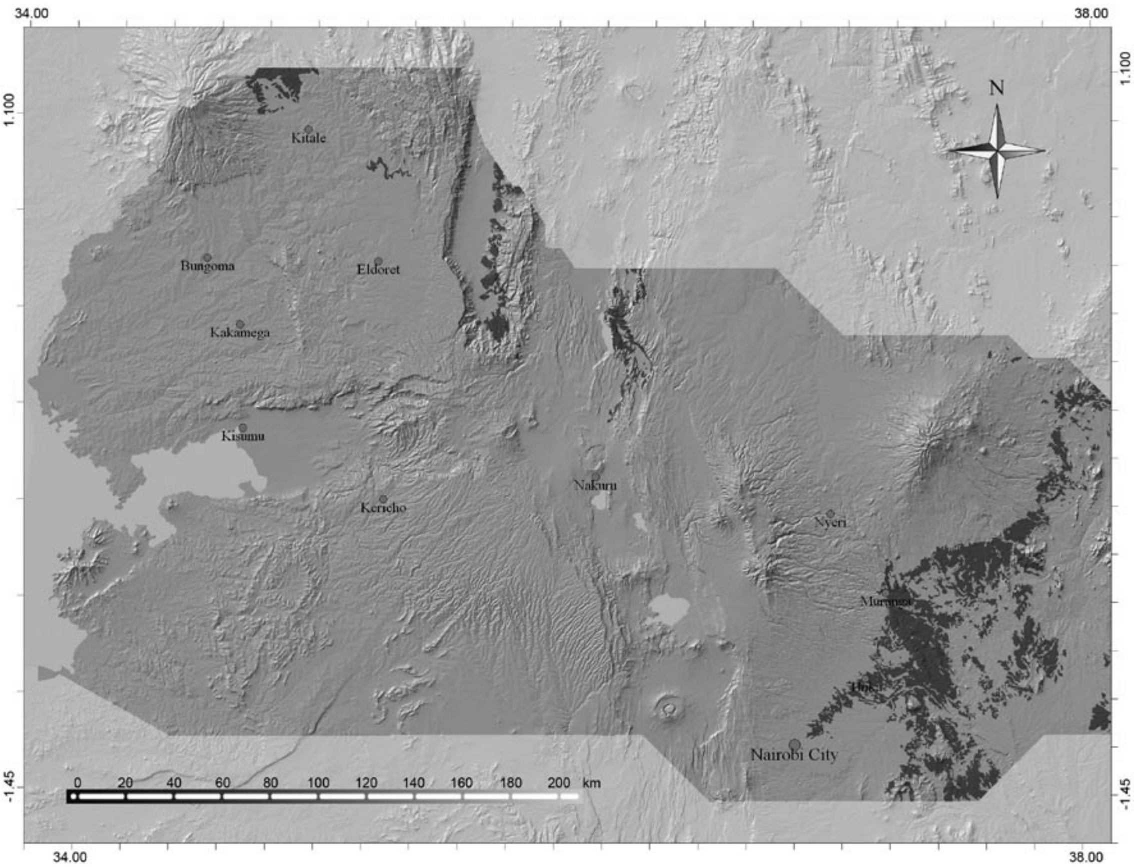
Upland Acacia woodland, savanna and bushland



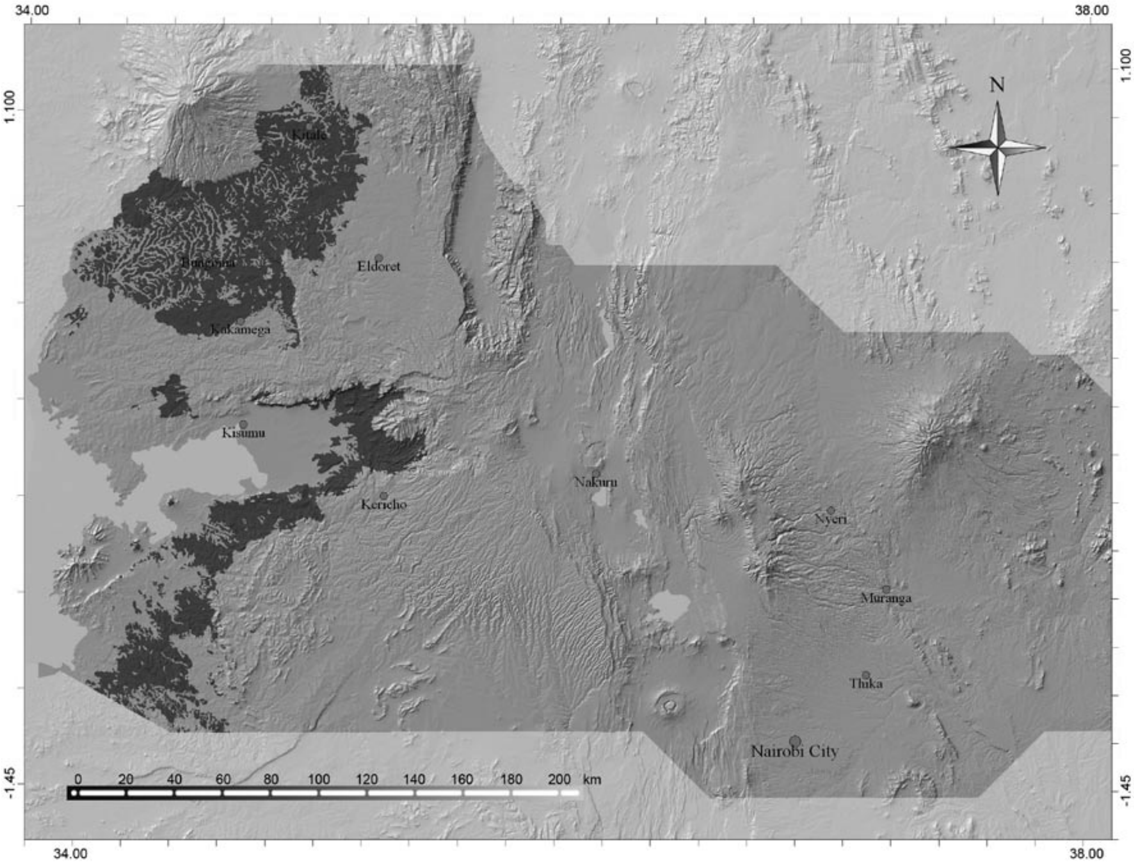
Broad-leaved savanna-evergreen bushland mixtures



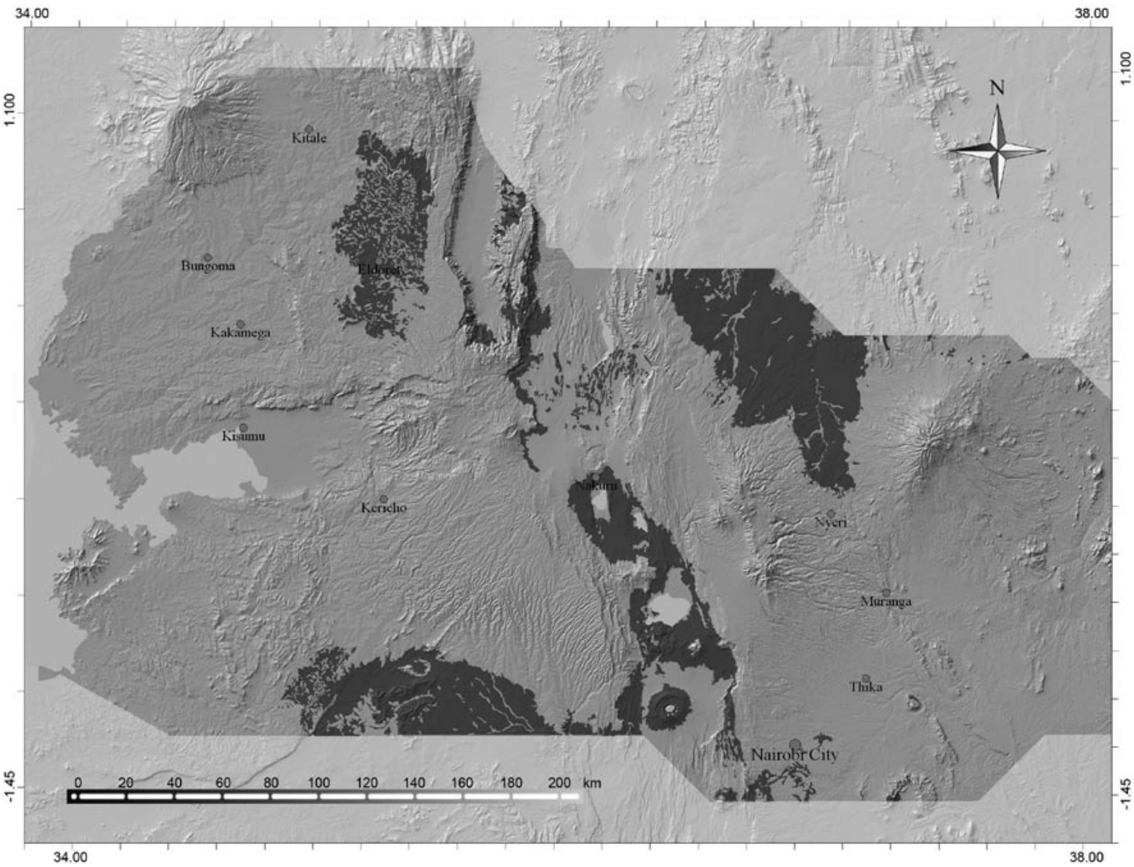
Lowland Acacia-Commiphora woodland, bushland and thicket



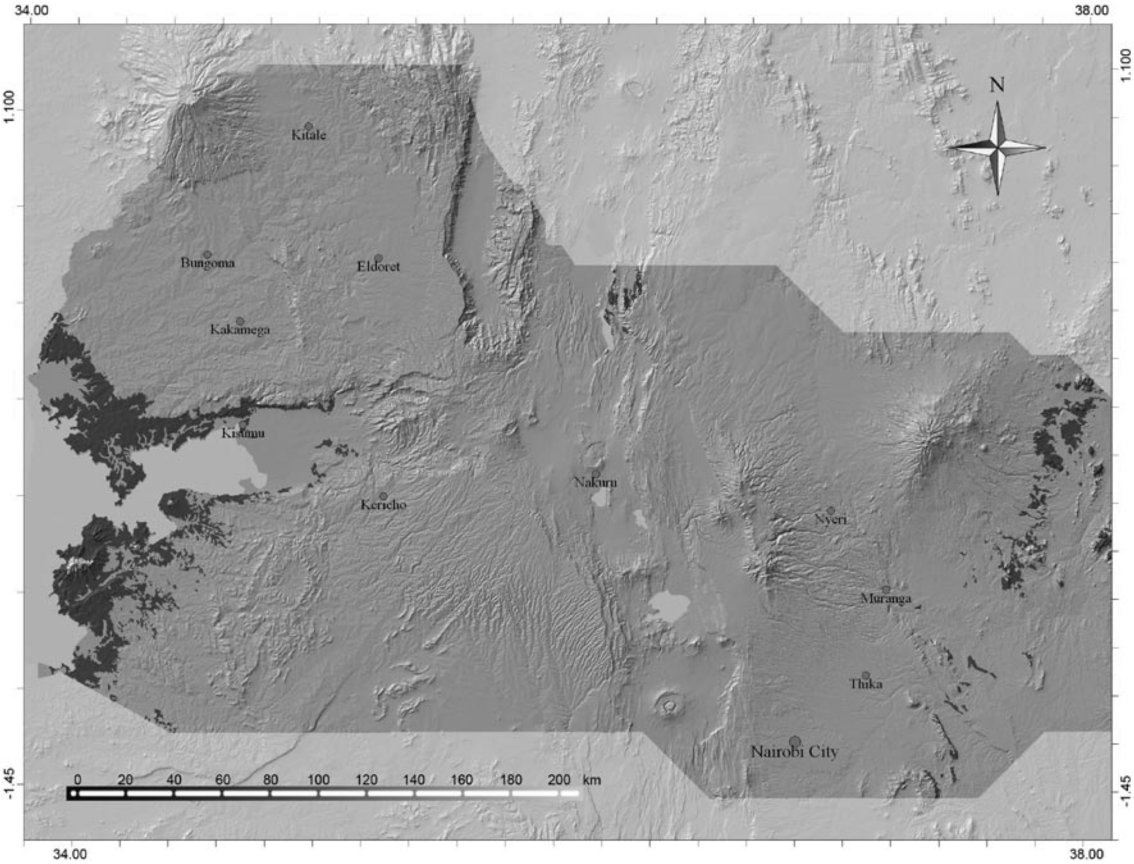
Dry Combretum savanna



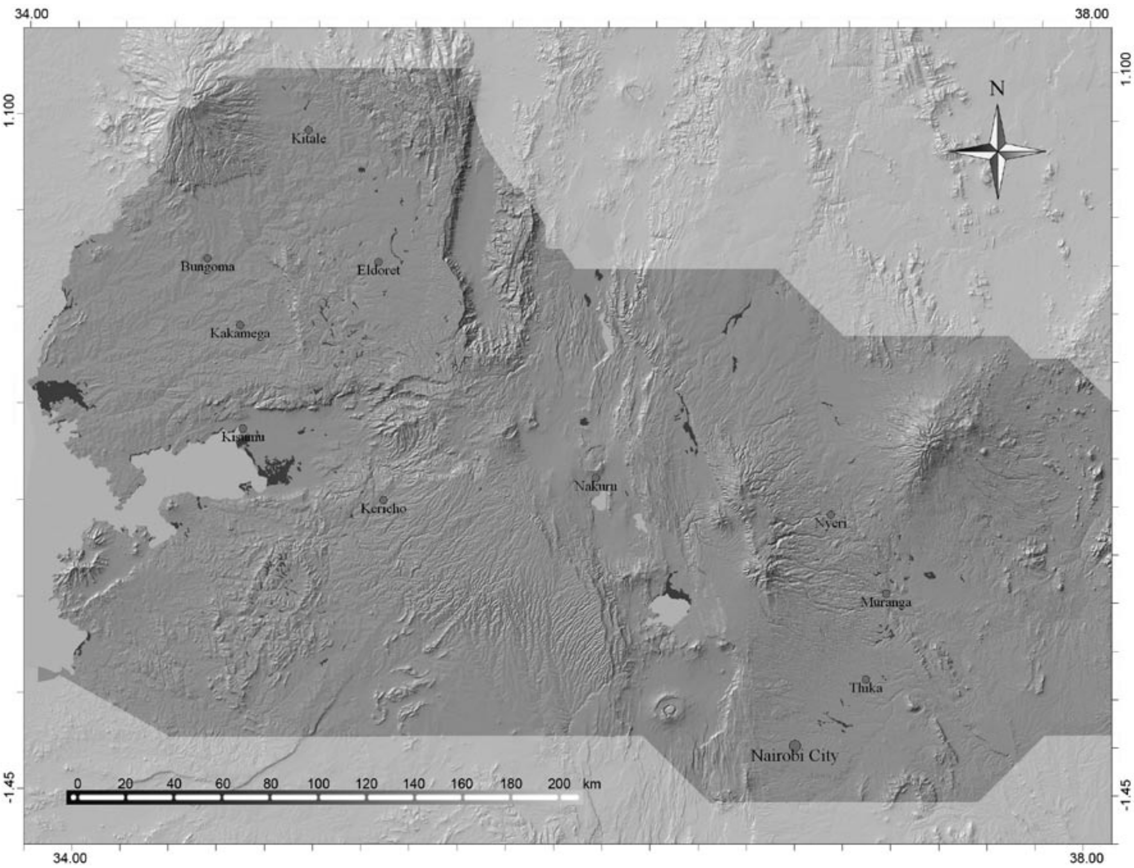
Moist Combretum-Terminalia savanna



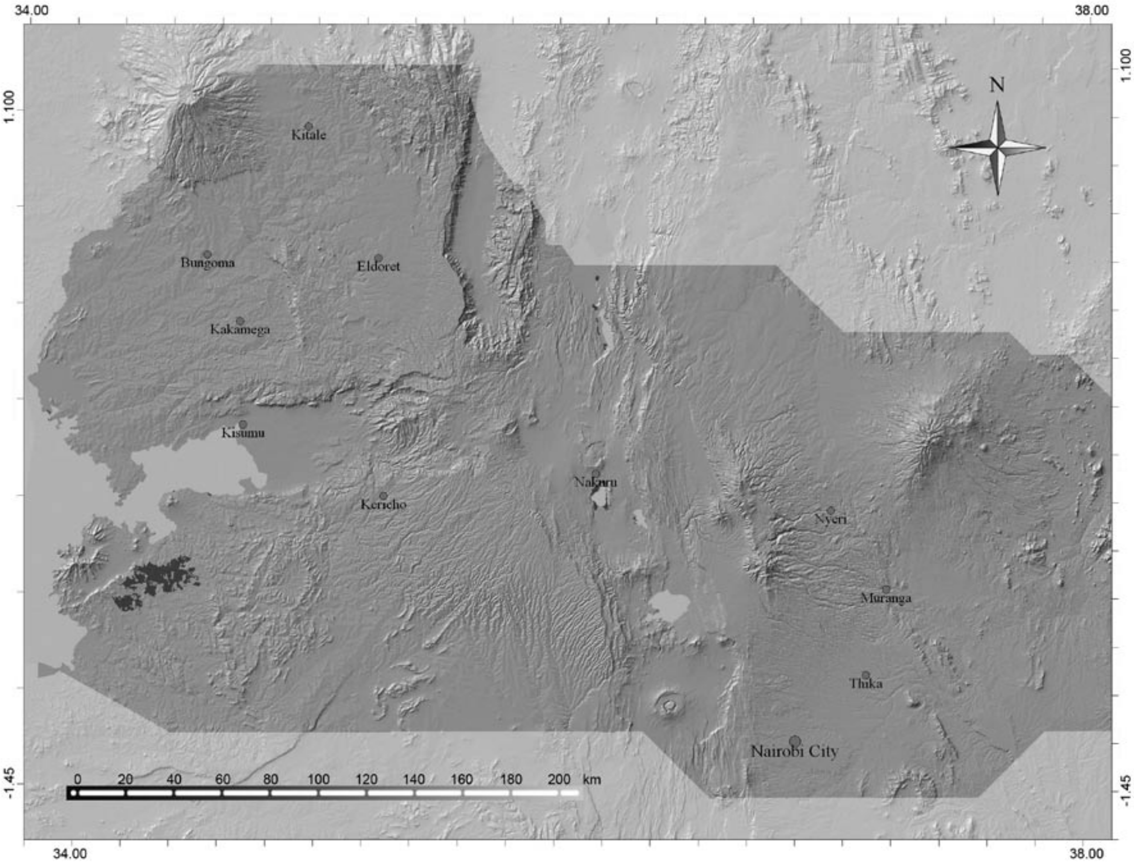
Evergreen and semi-evergreen bushland



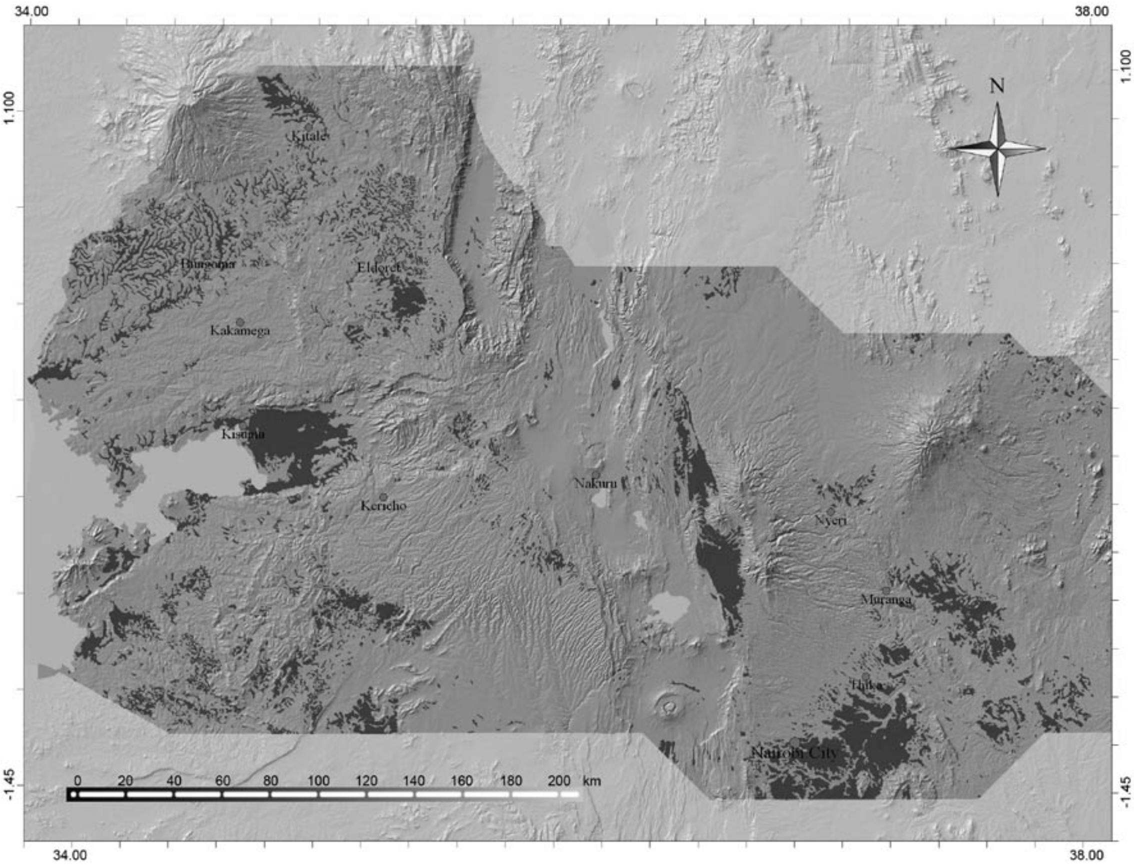
Semi evergreen thickets



Papyrus and swamp



Open grassland areas on clay plains



Acacia and allied vegetation on soils with impeded drainage

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Danish Centre for Forest, Landscape and Planning University of Copenhagen

Hørsholm Kongevej 11
DK-2970 Hørsholm
Tel: +45 3533 1500
www.SL.life.ku.dk
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